US005818312A

United States Patent [19]

Noguchi et al.

[11] **Patent Number: 5,818,312**

[45] **Date of Patent: Oct. 6, 1998**

[54] **DIELECTRIC FILTER**

[75] Inventors: **Toshiharu Noguchi**, Miyazaki-gun; **Kazuhiro Eguchi**, Miyazaki; **Hiroshi Ohno**, Miyazaki-gun, all of Japan

[73] Assignee: **Matsushita Electric Industrial Co., Ltd.**, Japan

[21] Appl. No.: **511,238**

[22] Filed: **Aug. 4, 1995**

Related U.S. Application Data

[62] Division of Ser. No. 202,073, Feb. 25, 1994, Pat. No. 5,499,004.

[30] **Foreign Application Priority Data**

Mar. 12, 1993 [JP] Japan 5-51945
Dec. 1, 1993 [JP] Japan 5-301565

[51] **Int. Cl.**[6] **H01P 1/205**

[52] **U.S. Cl.** **333/202**; 333/206; 333/222

[58] **Field of Search** .... 333/202, 206, 333/222, 202 DB

[56] **References Cited**

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64-37101	2/1989	Japan .	
53601	3/1989	Japan	333/202 DB
2-46085	12/1990	Japan .	
3-6103	1/1991	Japan .	
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Primary Examiner—Benny Lee
Attorney, Agent, or Firm—Rossi & Associates

[57] **ABSTRACT**

A dielectric filter includes two dielectric resonators each having a dielectric base body including first, second, third and fourth side surfaces and first and second end surfaces. A through hole is provided from the first end surface to the second end surface to define an inner surface. An outer conductor is located on and partially covers the four side surfaces. Uncovered portions of the second and third side surfaces are provided that are adjacent to each other and bounded by the outer conductor in three directions. An uncovered portion of the fourth side surface is adjacent to an uncovered portion of the first side surface and the first end surface, and is separated from the third side surface by the outer conductor. An inner conductor is located on the inner surface. A connection conductor is also located on the second end surface and connects the inner conductor to the outer conductor. An interstage coupling electrode is located on the uncovered portion of the first side surface. An area of the uncovered portion of the first side surface extends in at least three directions from the interstage coupling electrode and separates the interstage coupling electrode from the outer conductor. An input/output coupling electrode is located on the uncovered portion of the second and third side surfaces. Areas of the uncovered portions of the second and third side surfaces extend in three directions from the input/output coupling electrode and separate the input/output coupling electrode from the outer conductor. The the outer conductor of a first dielectric resonator is electrically connected to the outer conductor of a second dielectric resonator.

4 Claims, 21 Drawing Sheets

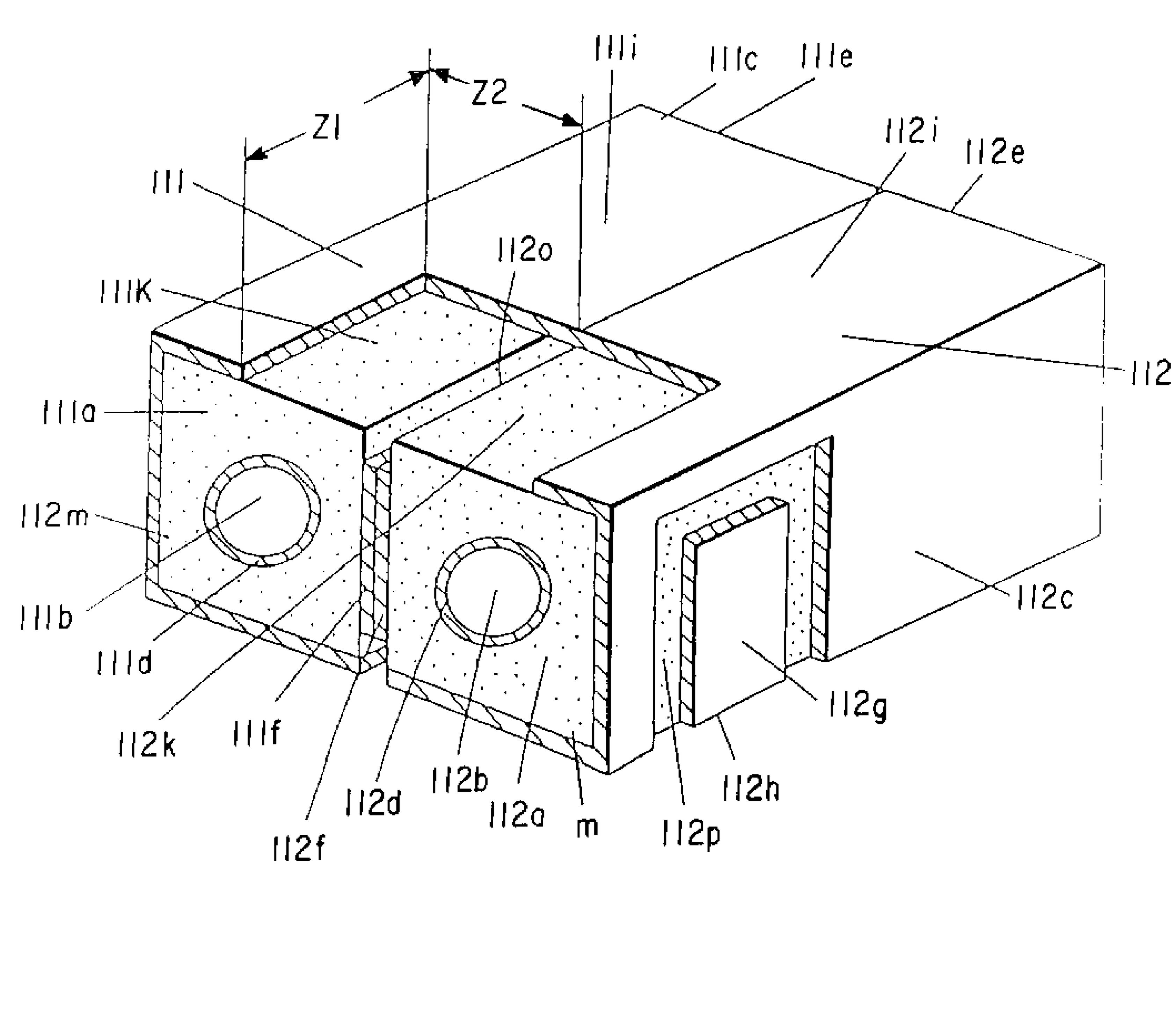
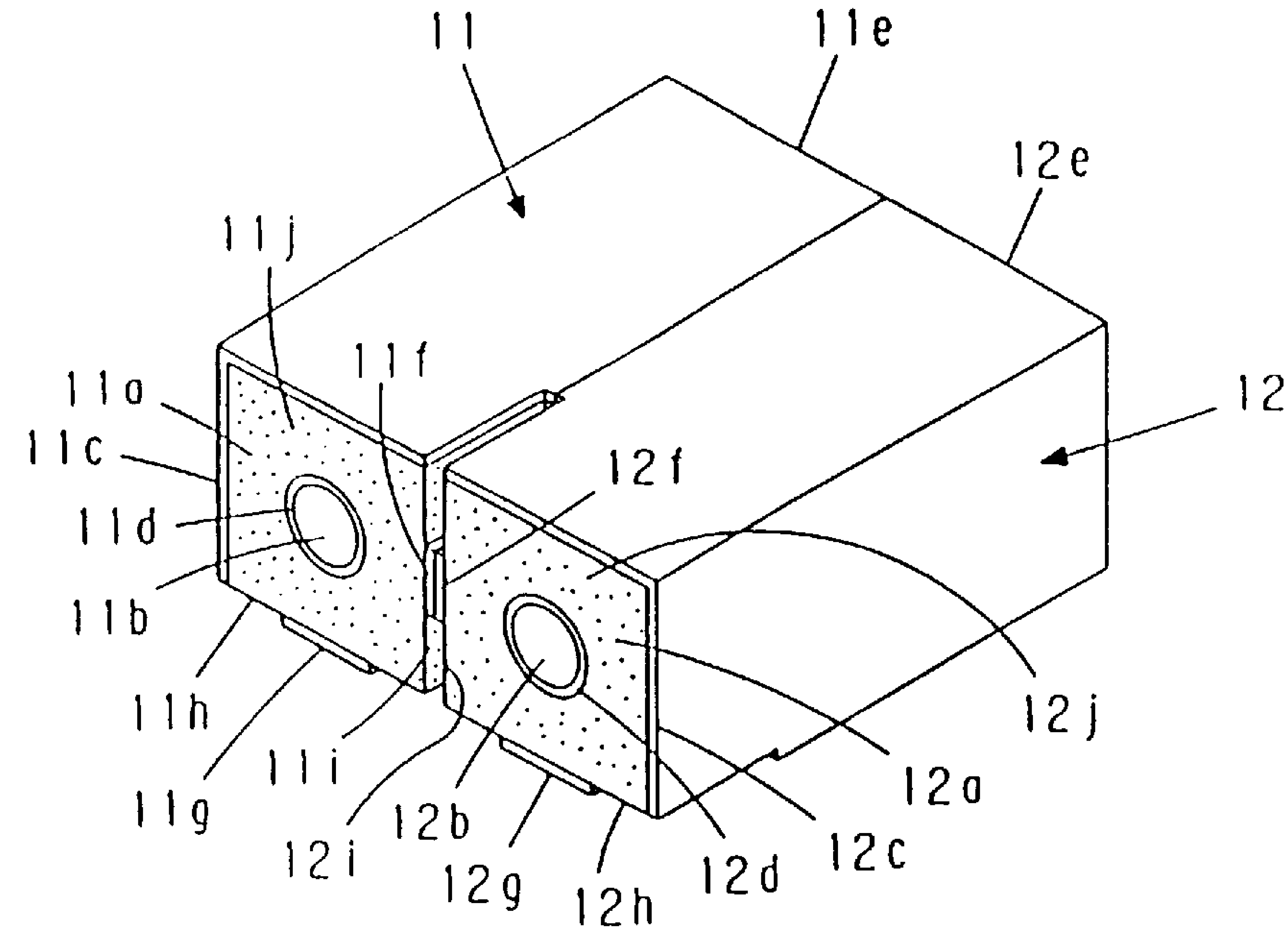


FIG. 1


11
11e
12e
11j
11a
11c
11f
12f
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11d
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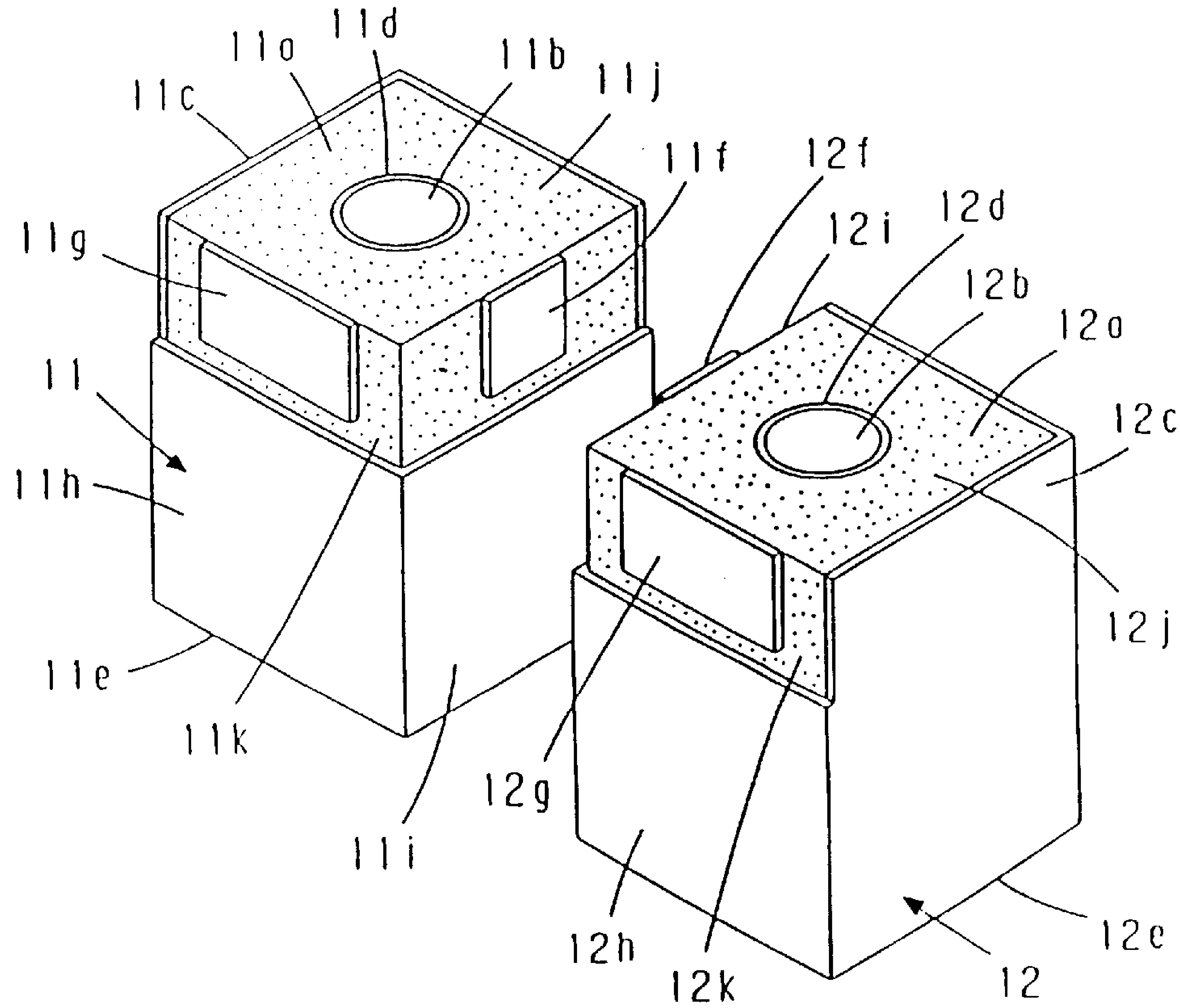
11g
11i
12i
12b
12g
12h
12d
12c
12a
12j

FIG. 2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11d
11b
11j
11c
11f
12f
12i
12d
12b
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11g
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11h
12c
12j
11e
11k
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12g
12h
12k
12
12e

FIG. 3

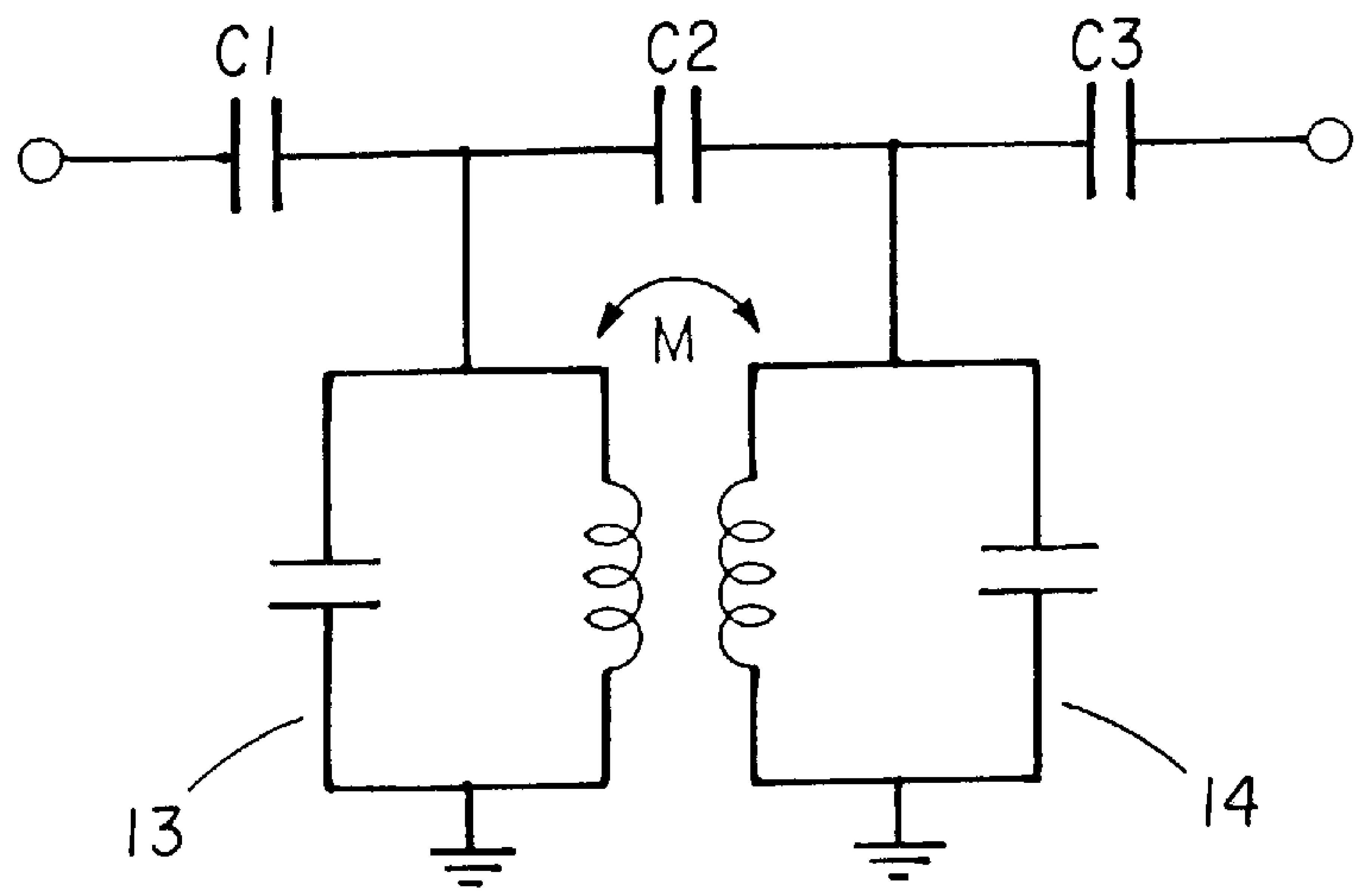


FIG. 4

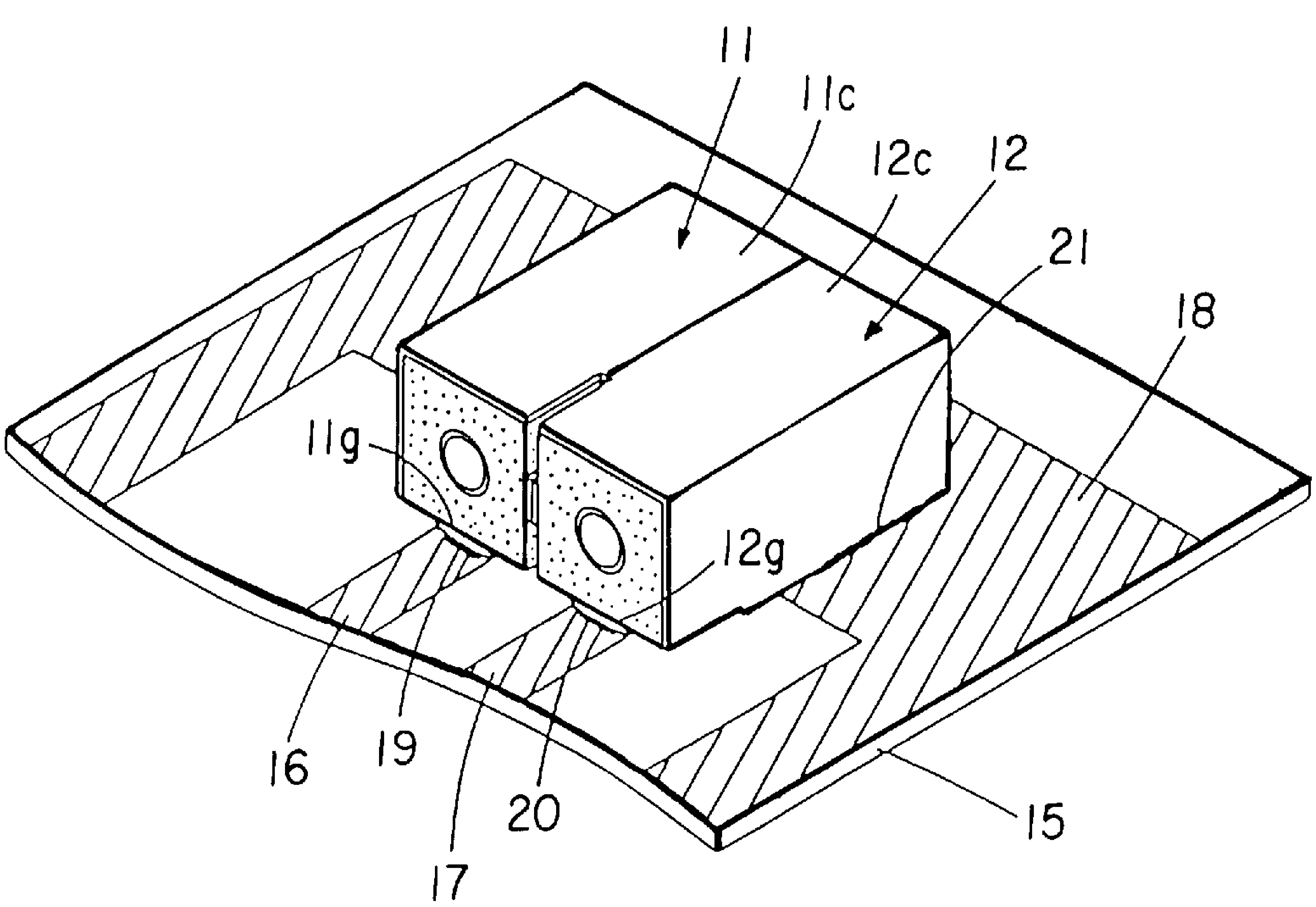


FIG. 5

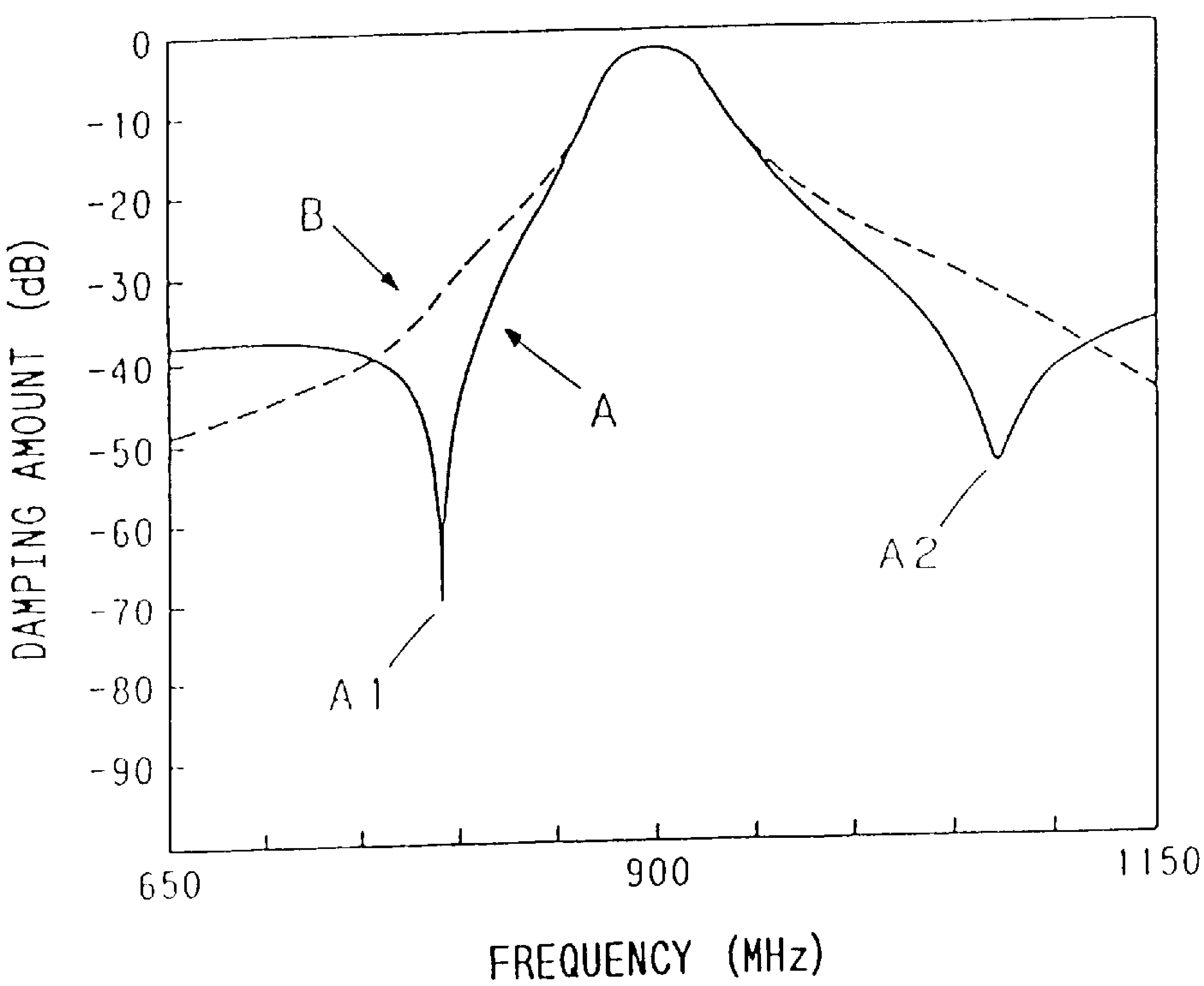

0
-10
-20
-30
-40
-50
-60
-70
-80
-90
DAMPING AMOUNT (dB)
650
900
1150
FREQUENCY (MHz)
B
A
A1
A2

FIG. 6

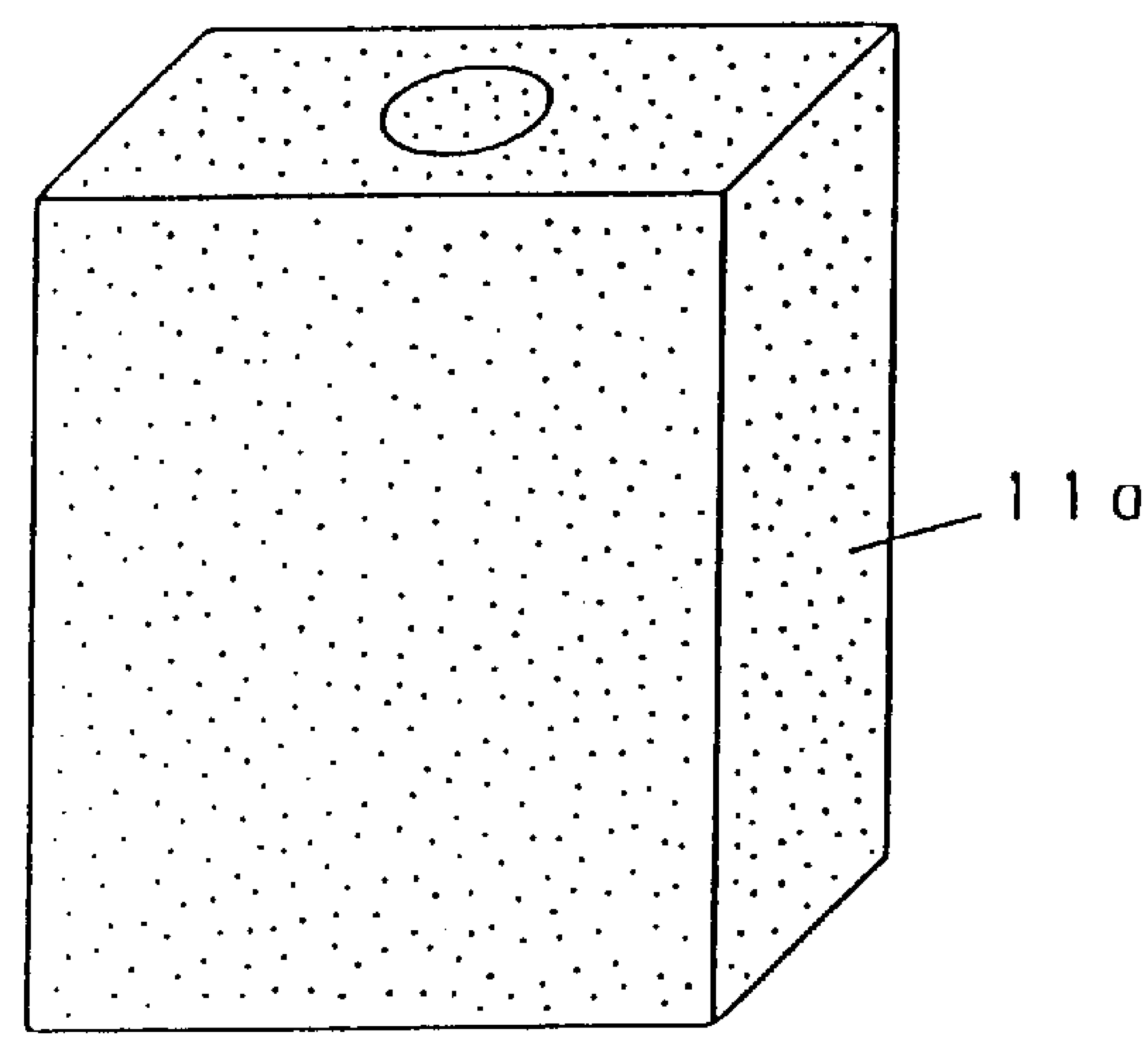


FIG. 7

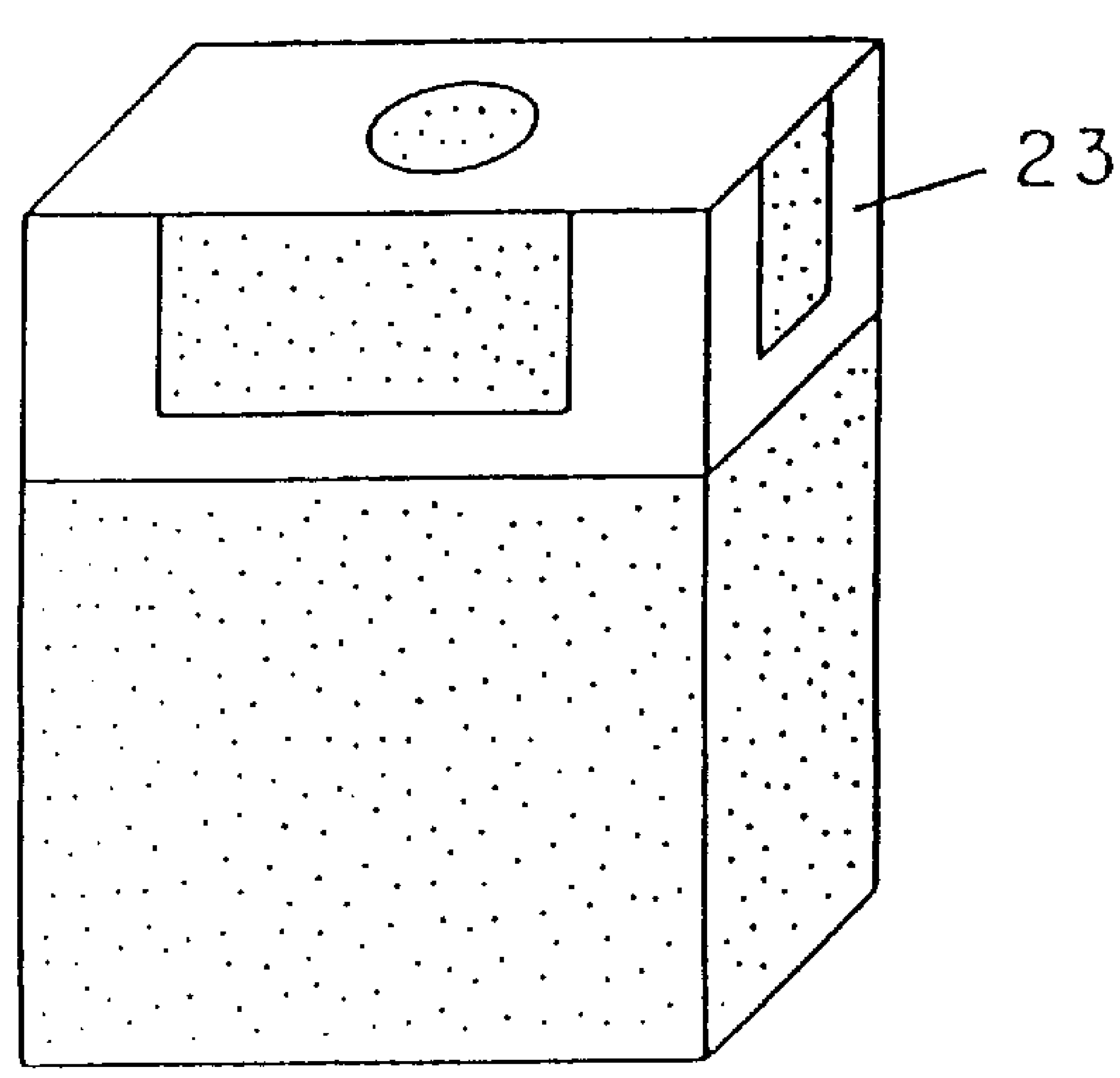


FIG. 8

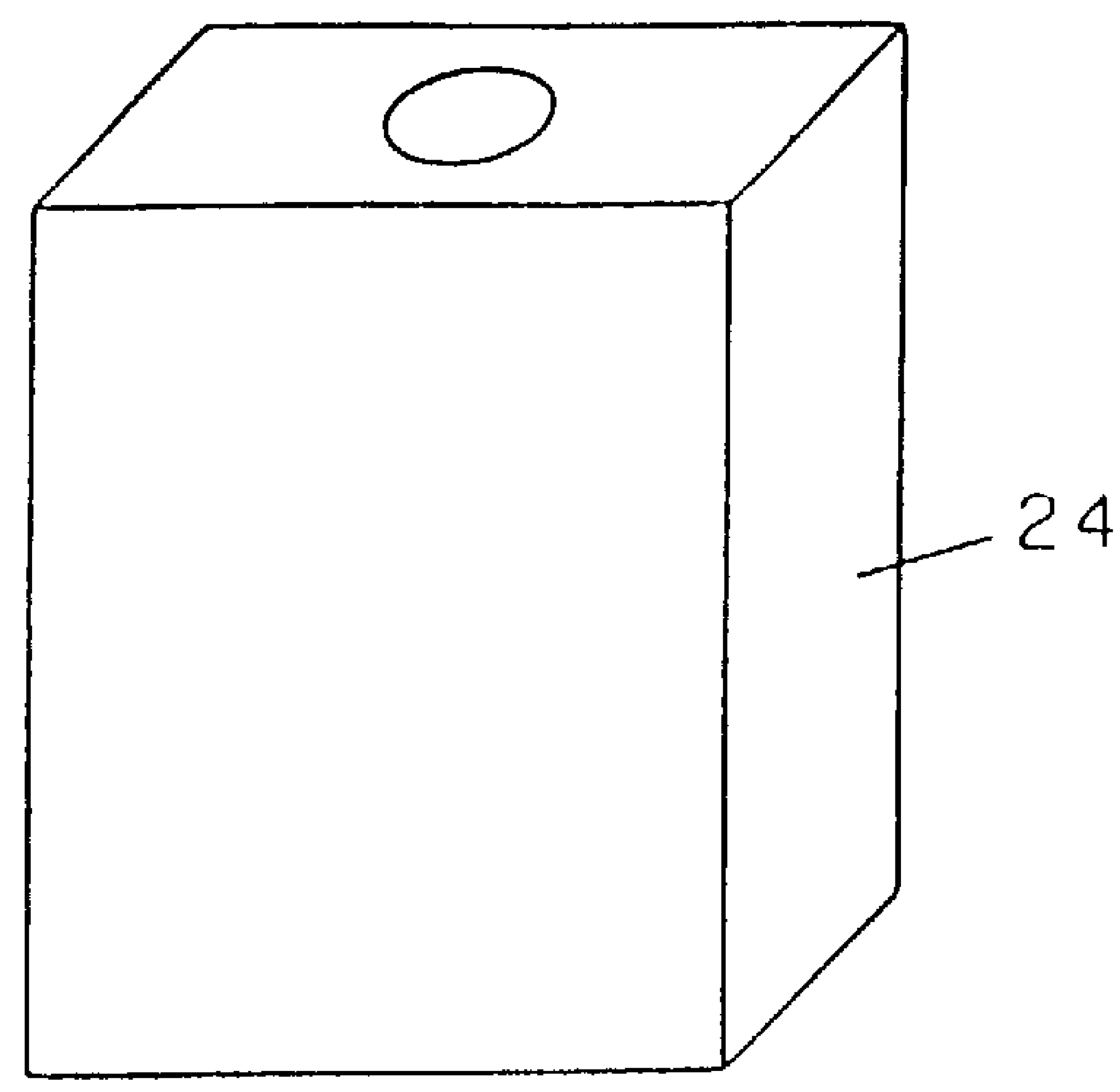


FIG. 9

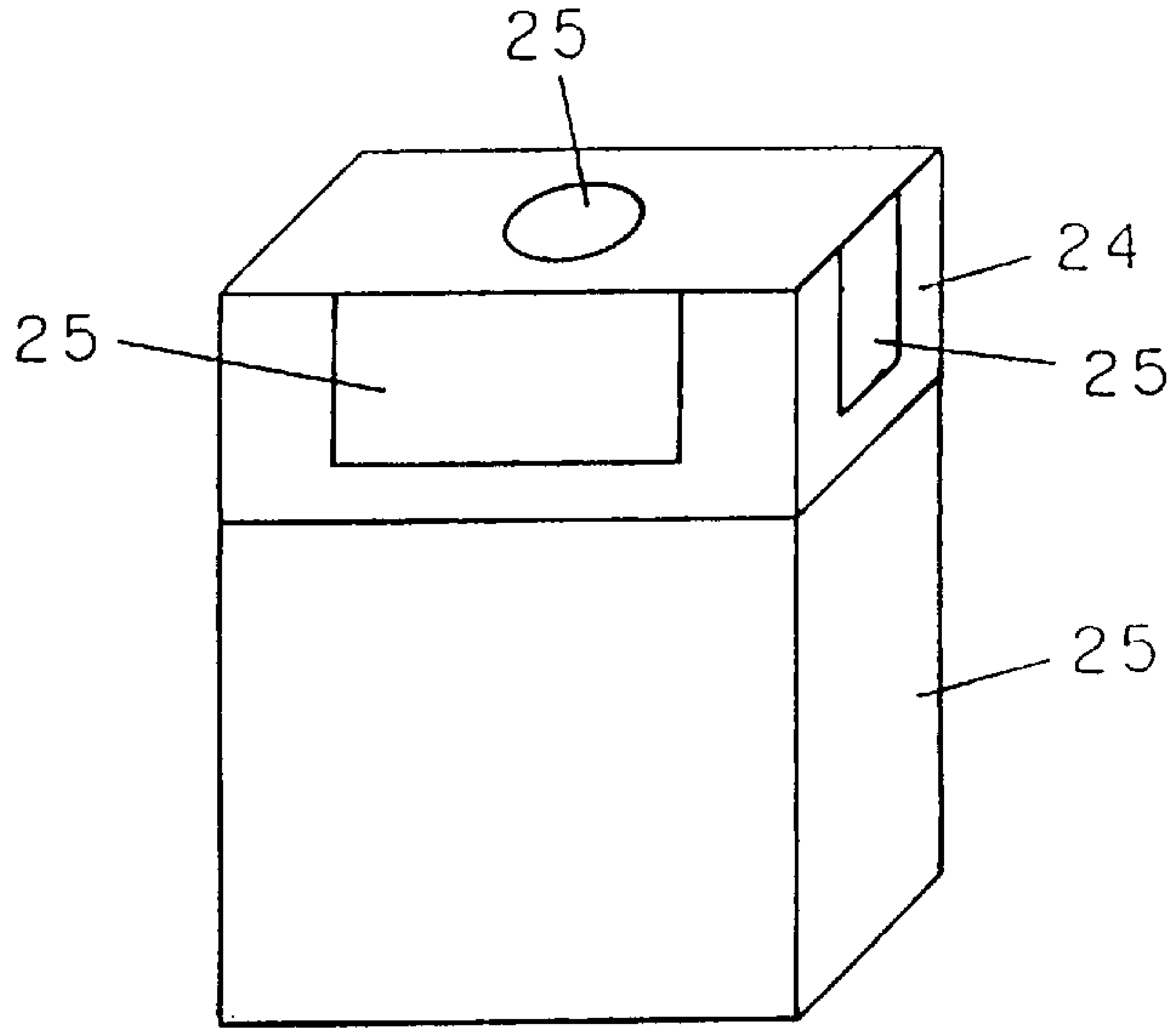


FIG. 10

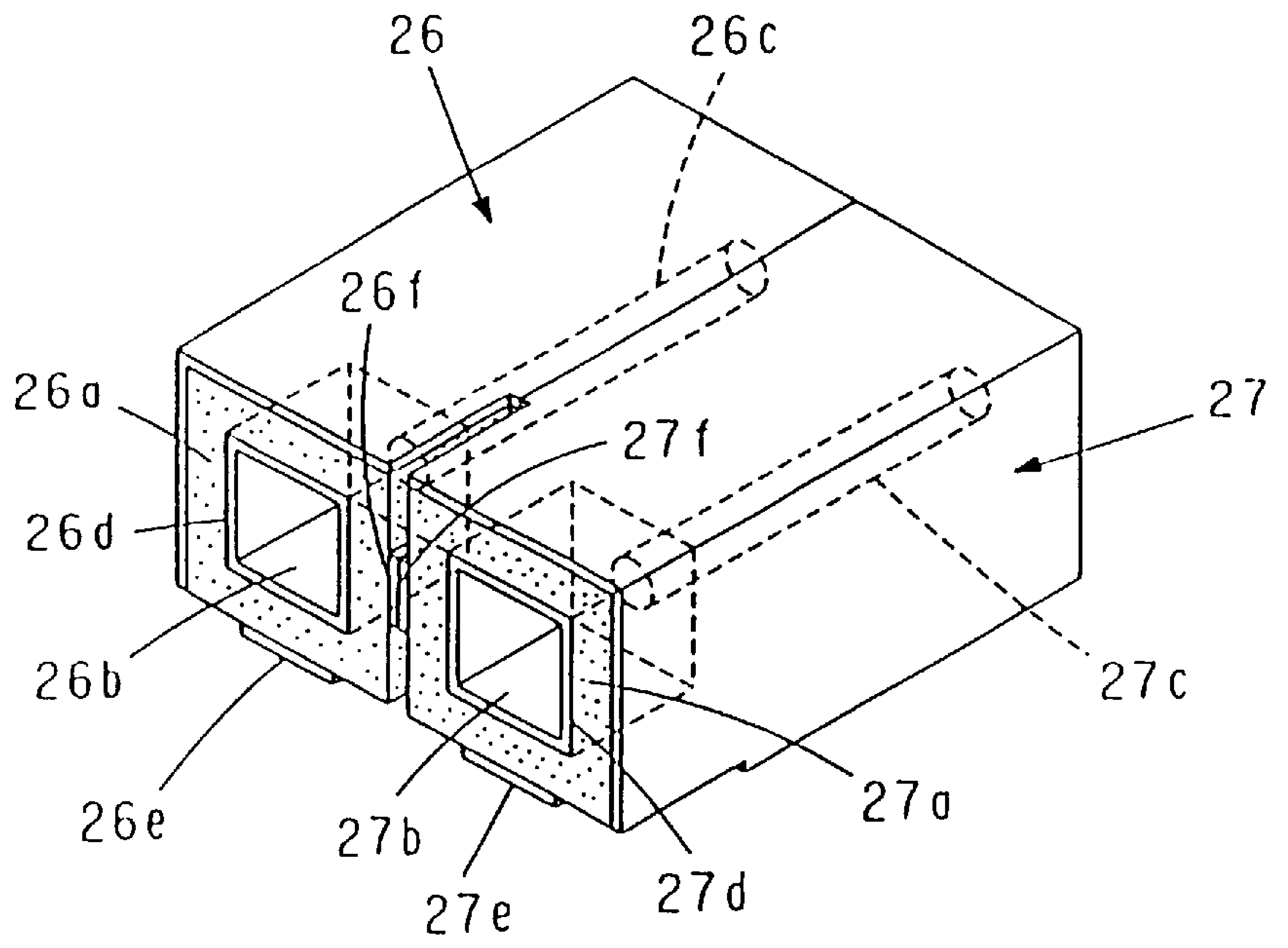

26
26c
26f
26a
27f
27
26d
26b
27c
26e
27b
27a
27e
27d

FIG. 11

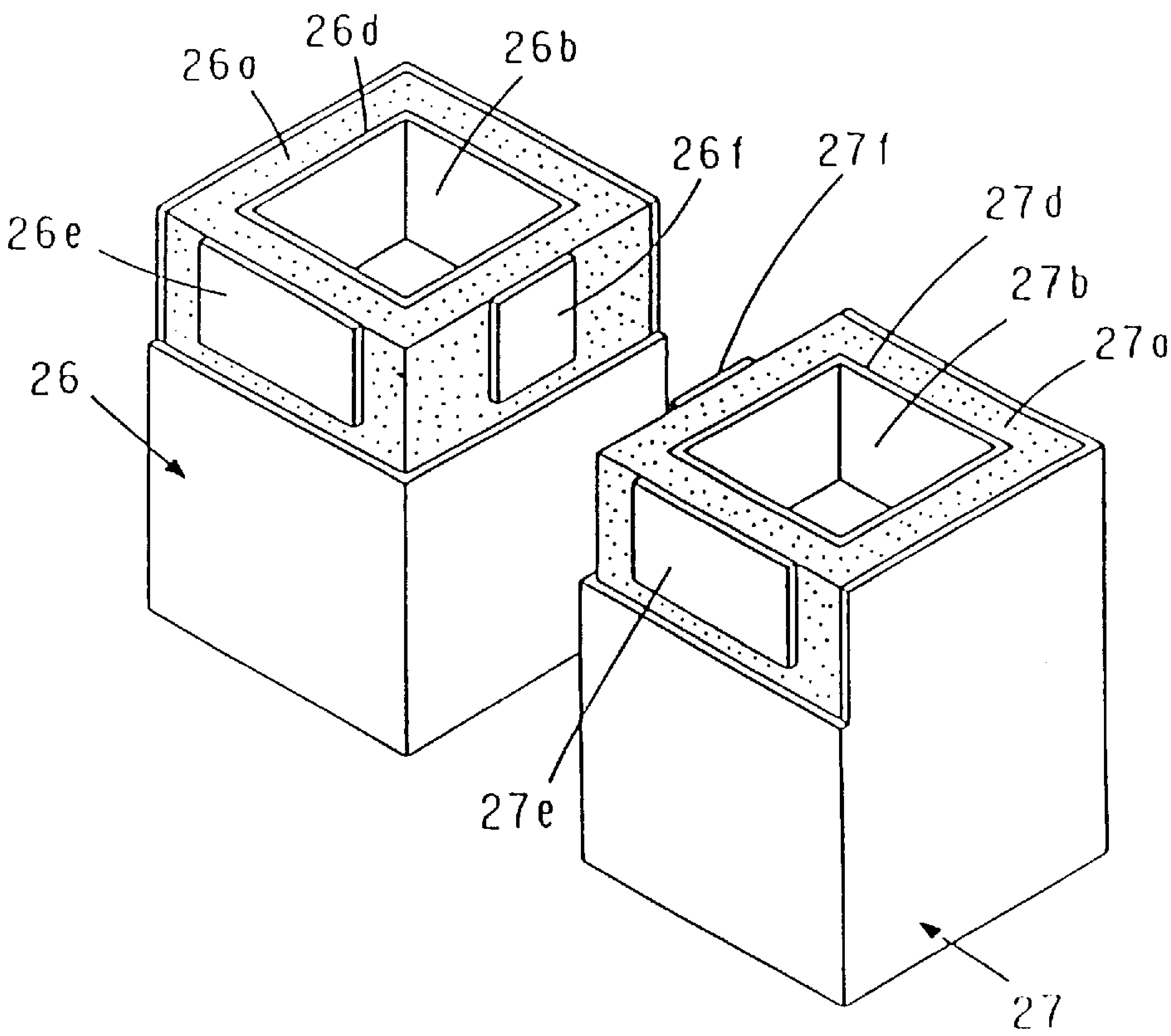

26a
26d
26b
26f
27f
27d
26e
27b
27a
26
27e
27

FIG. 12

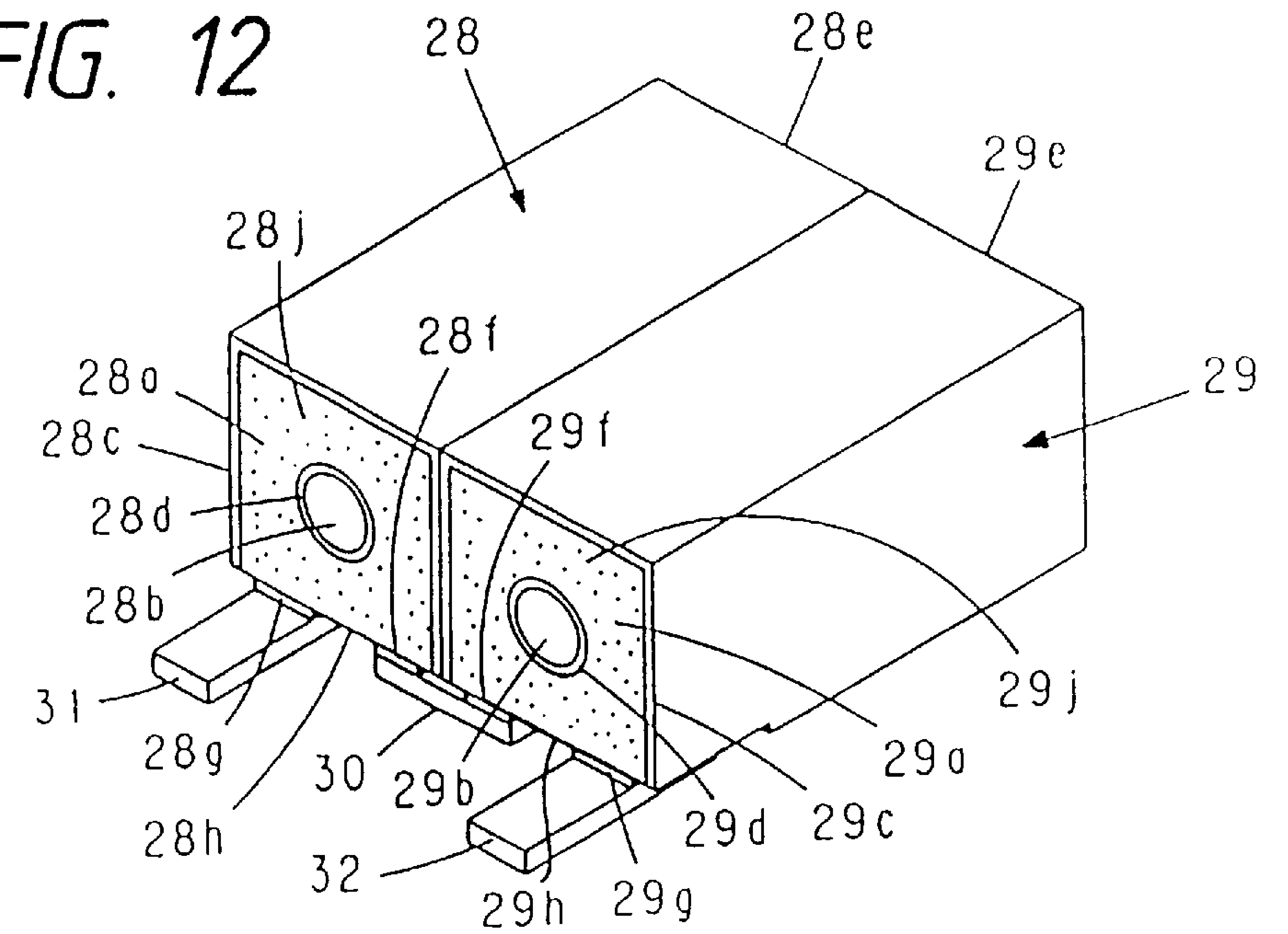

28
28e
29e
28j
28f
29
28a
28c
29f
28d
28b
29j
31
28g
30
29b
29a
28h
29d
29c
32
29h
29g

FIG. 13

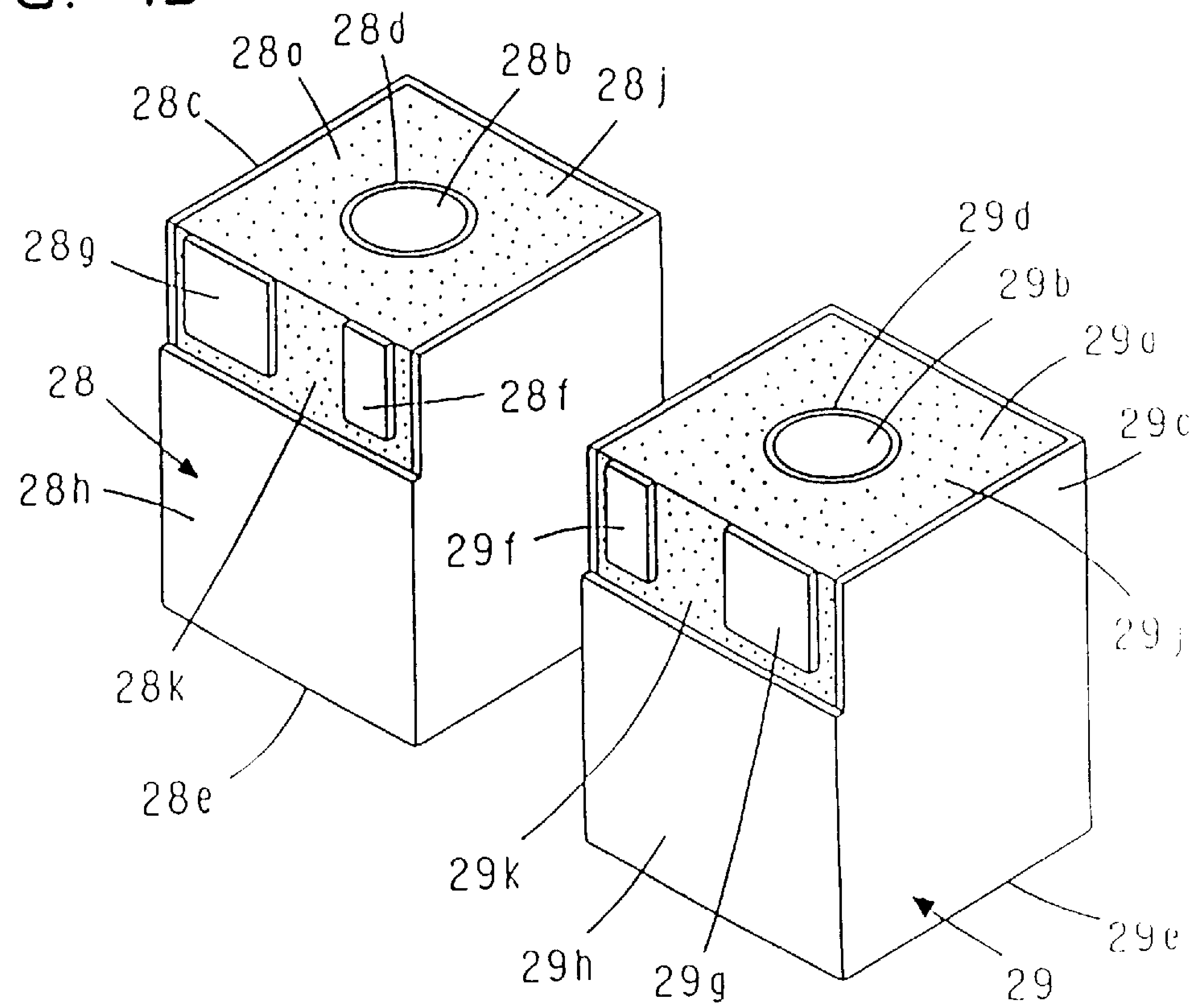

28d
28a
28b
28c
28j
29d
28g
29b
29a
28
29c
28f
28h
29f
29j
28k
28e
29k
29e
29h
29g
29

FIG. 14

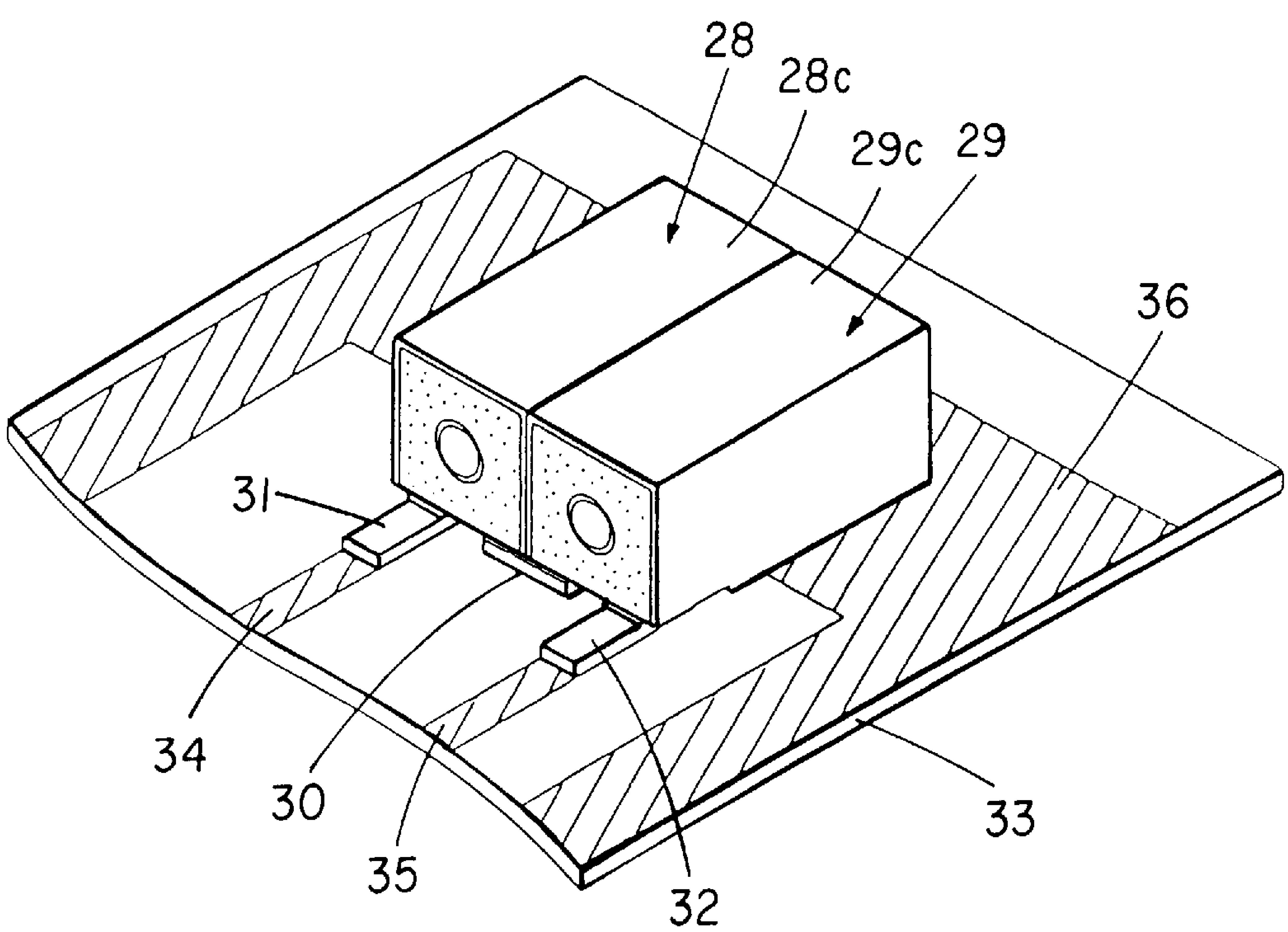


FIG. 15

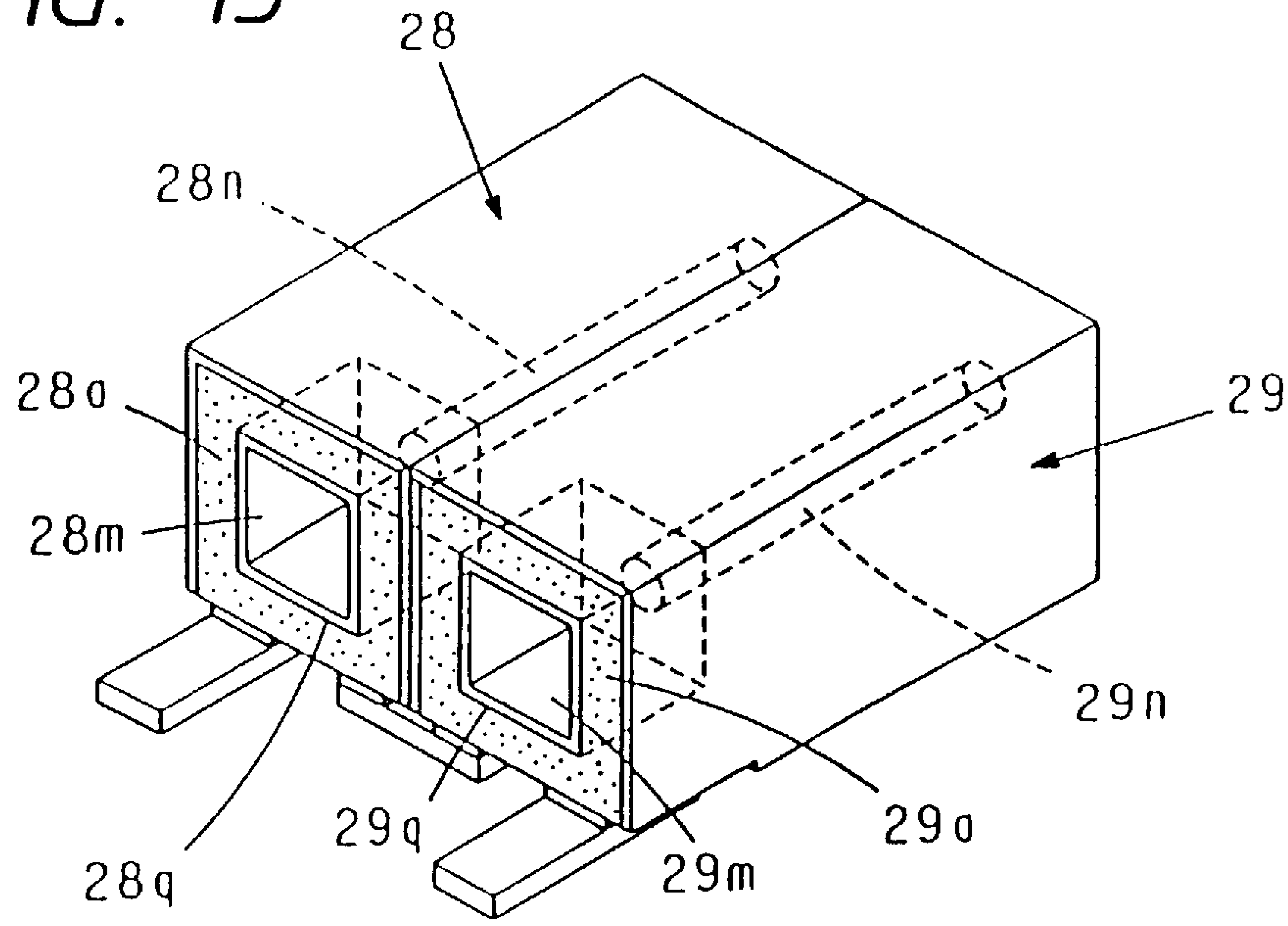

28
28n
28a
28m
29
29n
28q
29q
29m
29a

FIG. 16

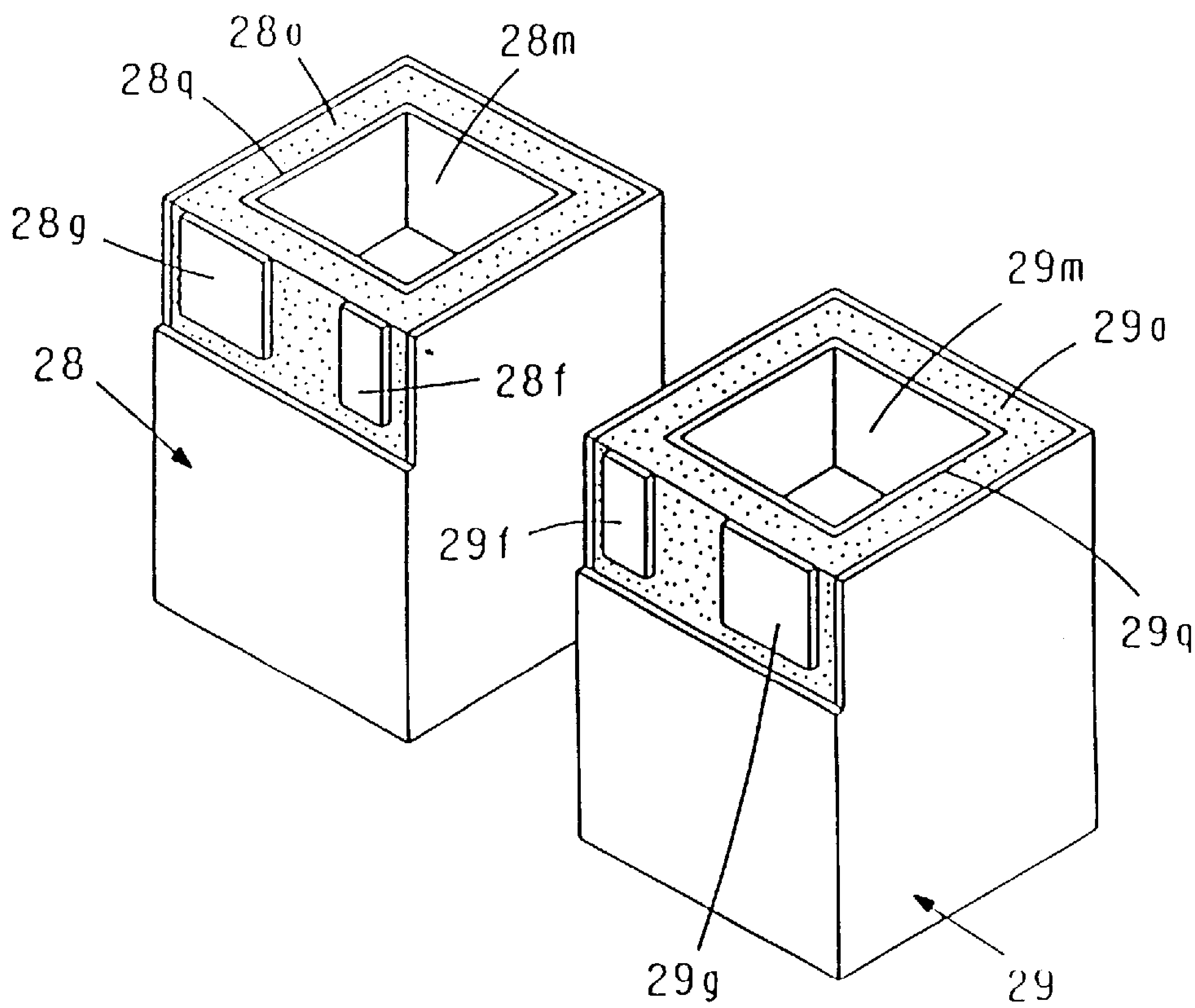

28a
28q
28m
28g
28
28f
29m
29a
29f
29q
29g
29

FIG. 17

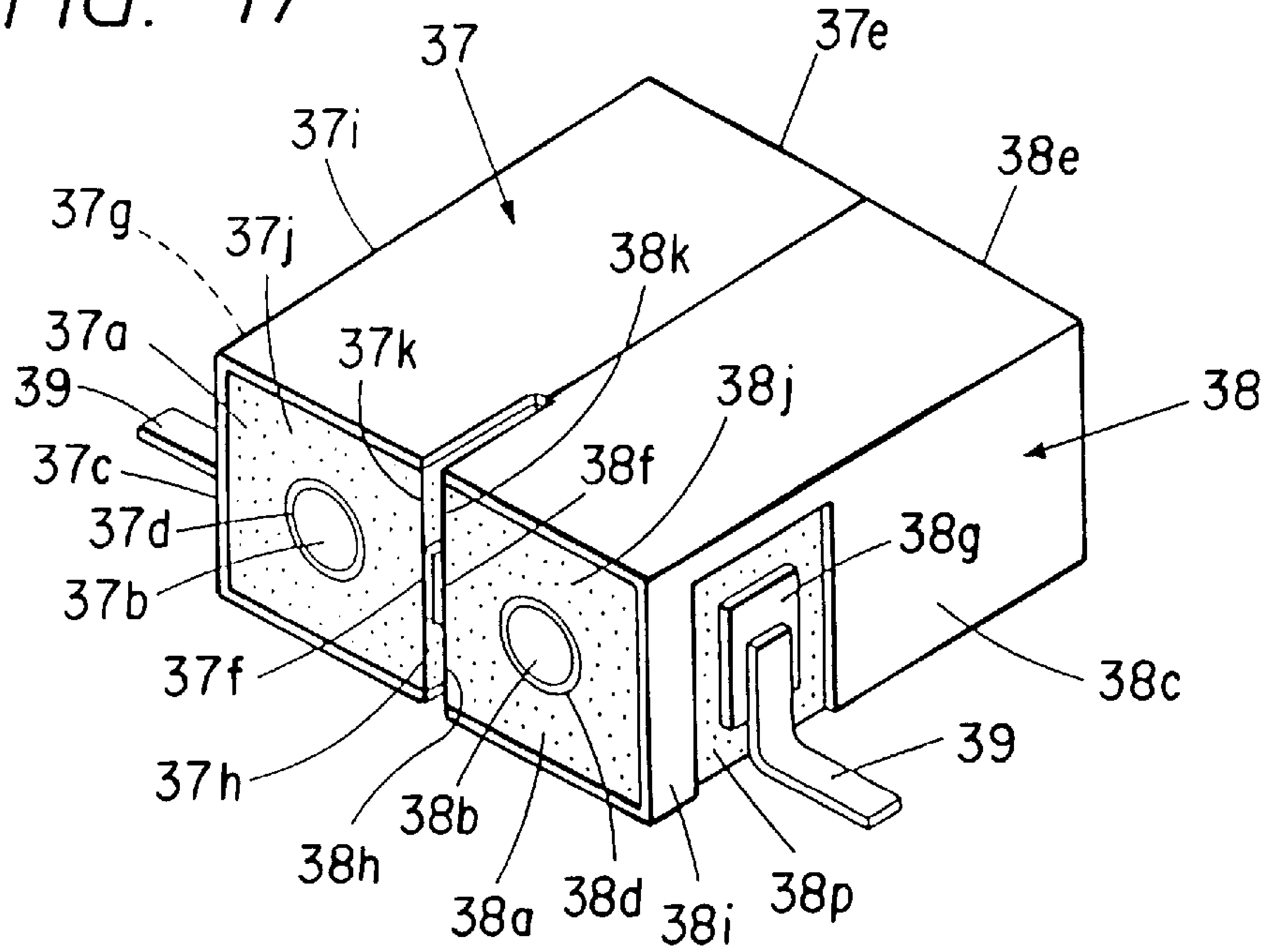

37
37e
37i
38e
37g
37j
38k
37a
37k
38
39
38j
37c
38f
37d
38g
37b
37f
38c
39
37h
38b
38h
38a
38d
38i
38p

FIG. 18

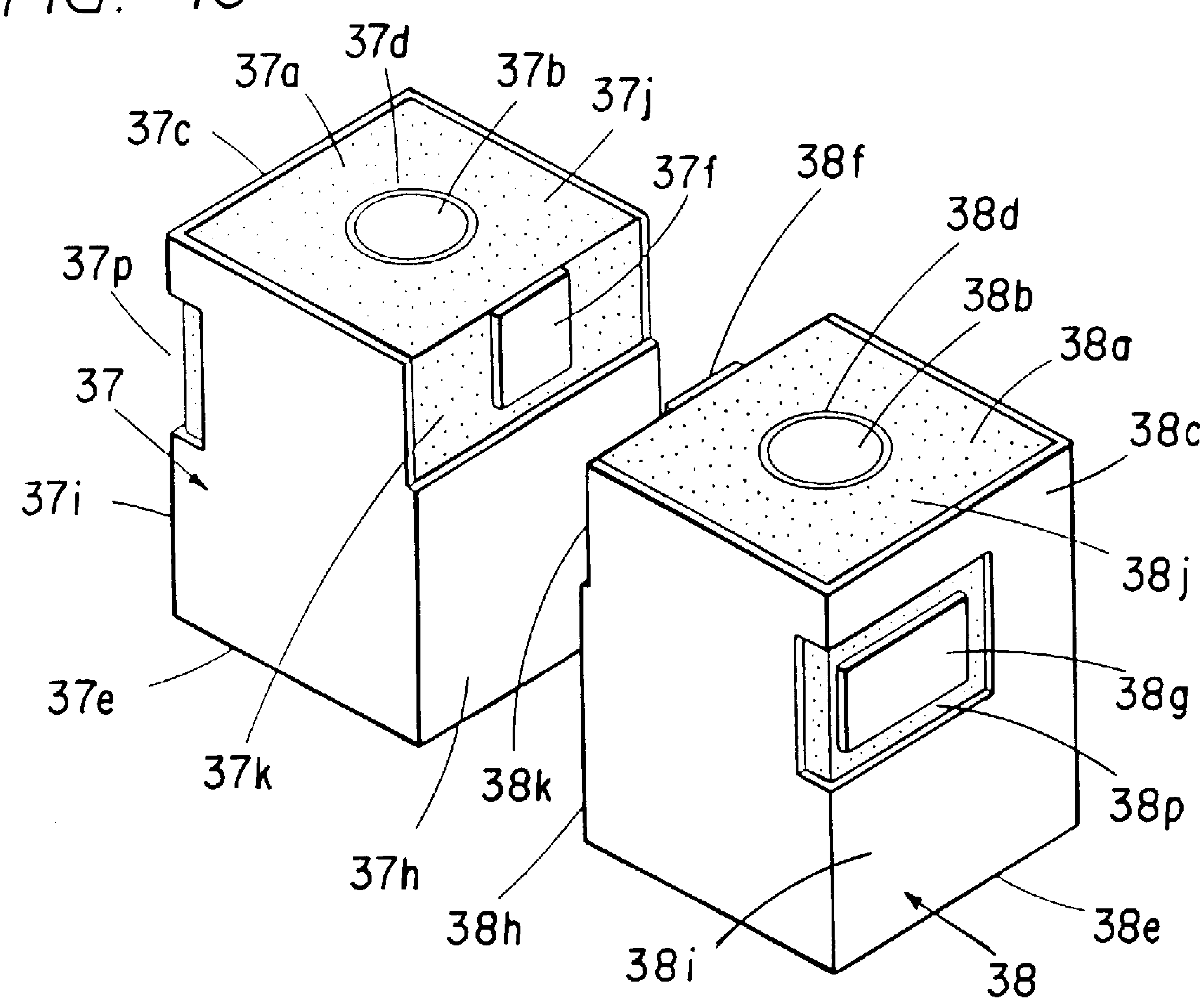

37d
37a
37b
37j
37c
37f
38f
38d
37p
38b
38a
37
38c
37i
38j
38g
37e
37k
38k
38p
37h
38h
38i
38e
38

FIG. 19

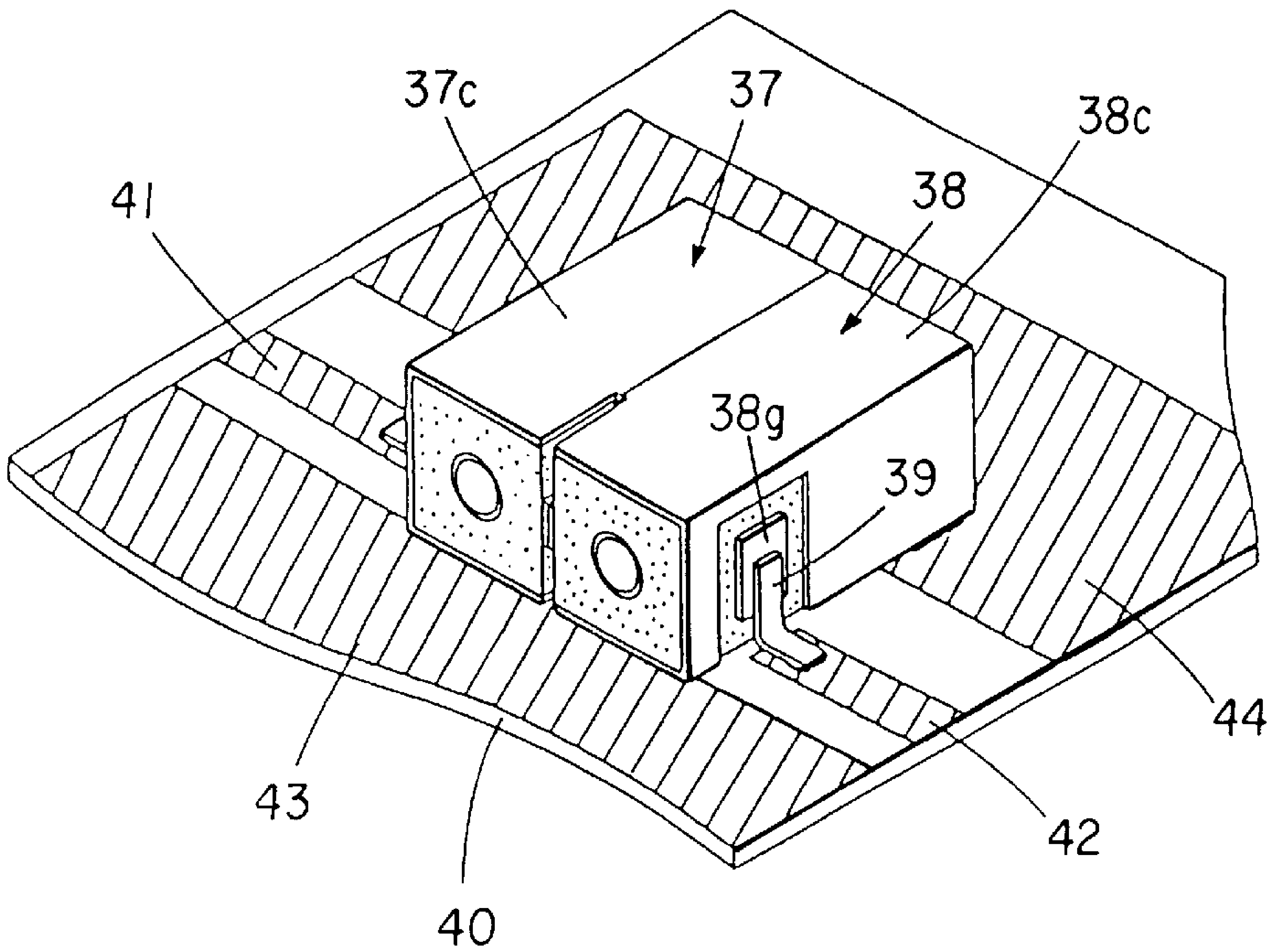


FIG. 20

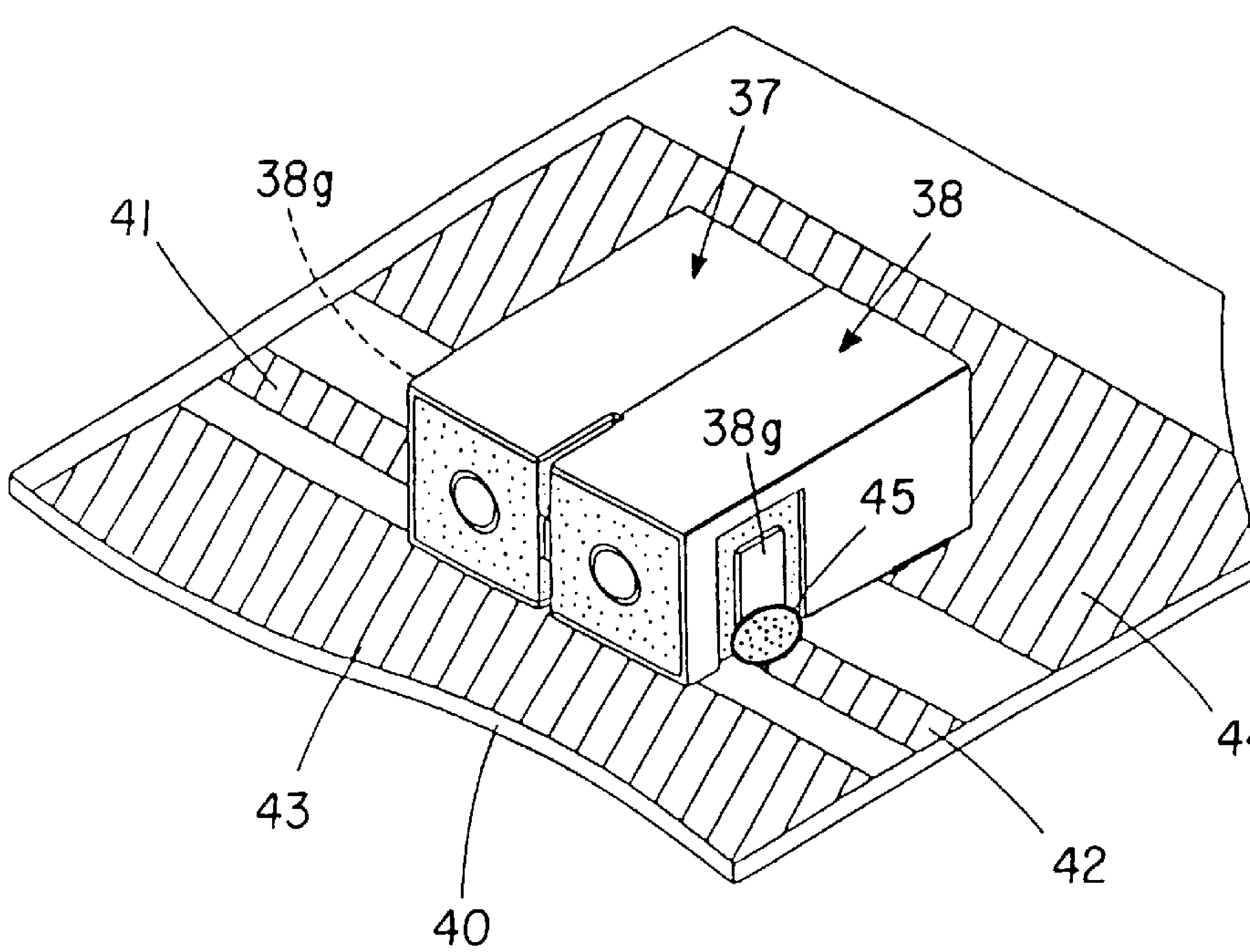


FIG. 21

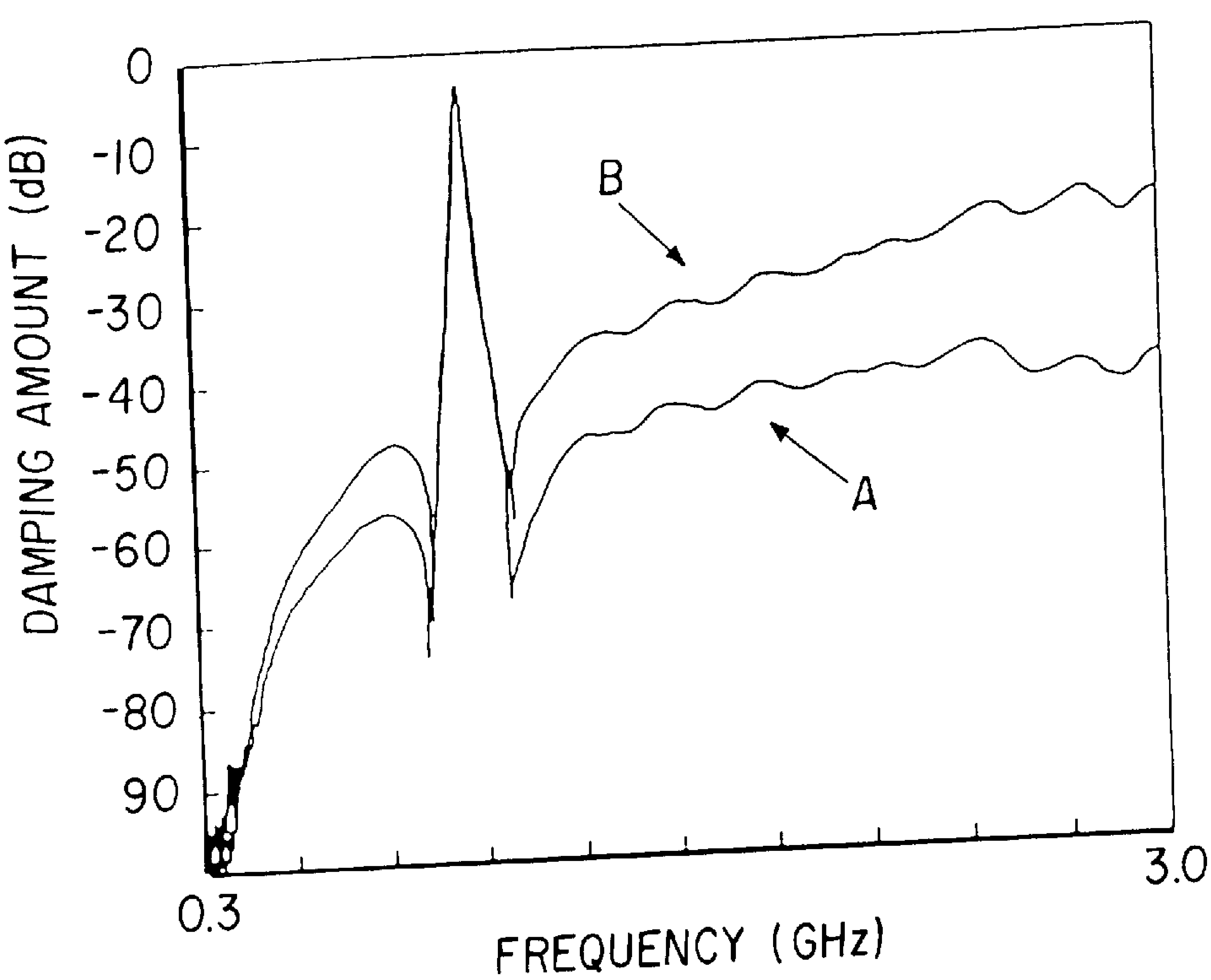

0
-10
-20
-30
-40
-50
-60
-70
-80
90
DAMPING AMOUNT (dB)
B
A
0.3
3.0
FREQUENCY (GHz)

FIG. 22

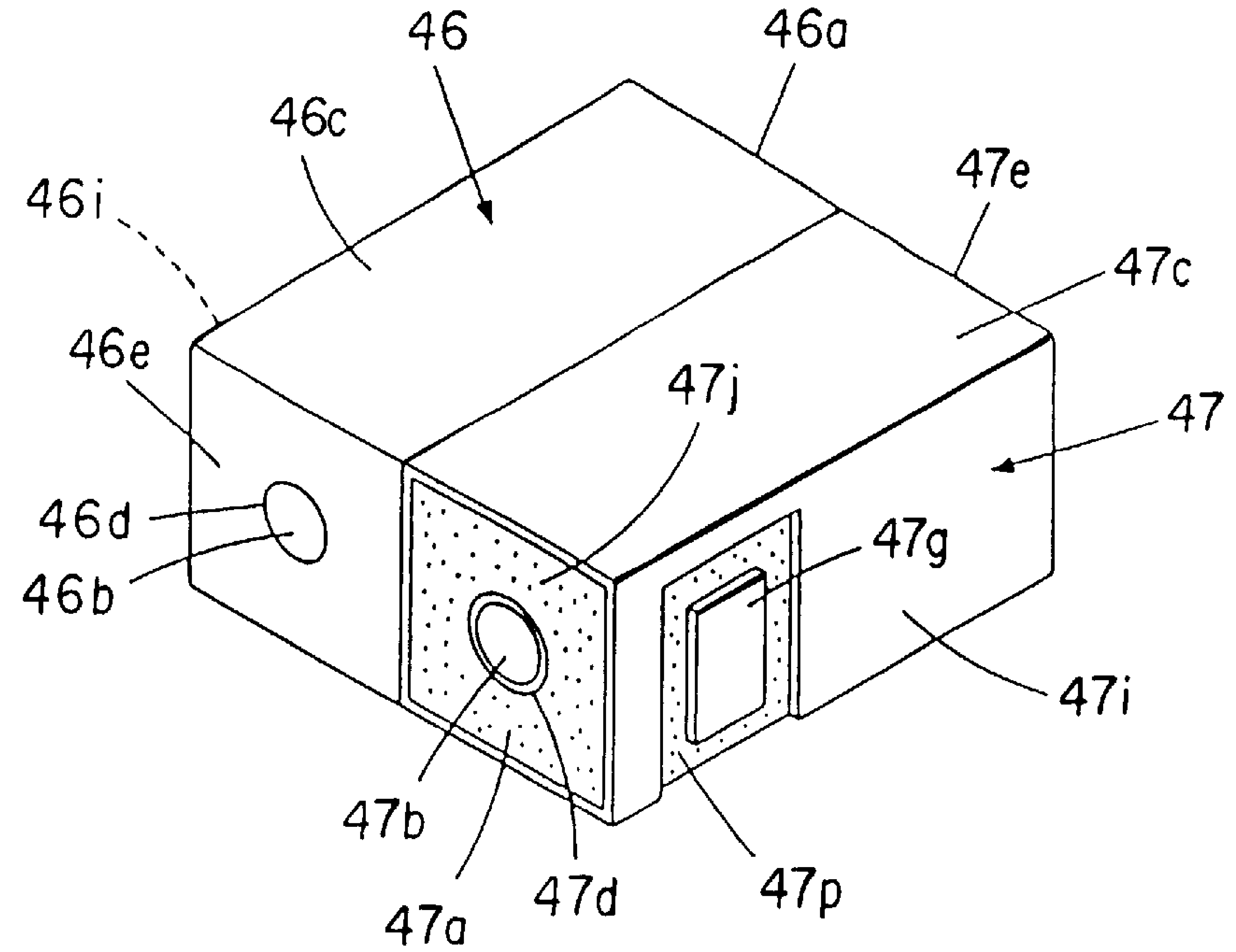

46
46a
46c
46i
47e
47c
46e
47j
47
46d
46b
47g
47i
47b
47a
47d
47p

FIG. 23

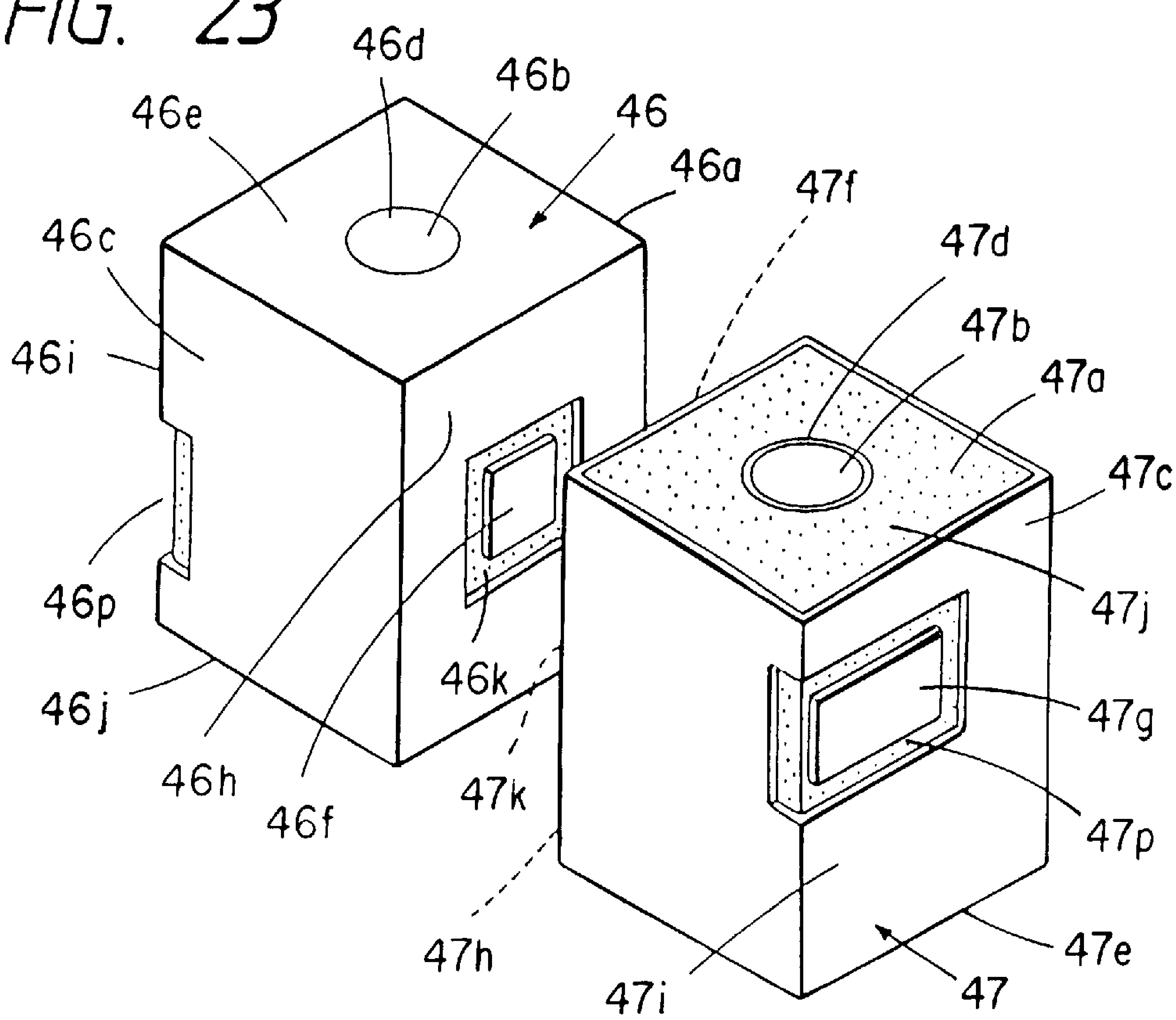

46d
46b
46e
46
46a
47f
46c
47d
47b
46i
47a
47c
46p
47j
46k
47g
46j
46h
46f
47k
47p
47h
47i
47
47e

FIG. 24

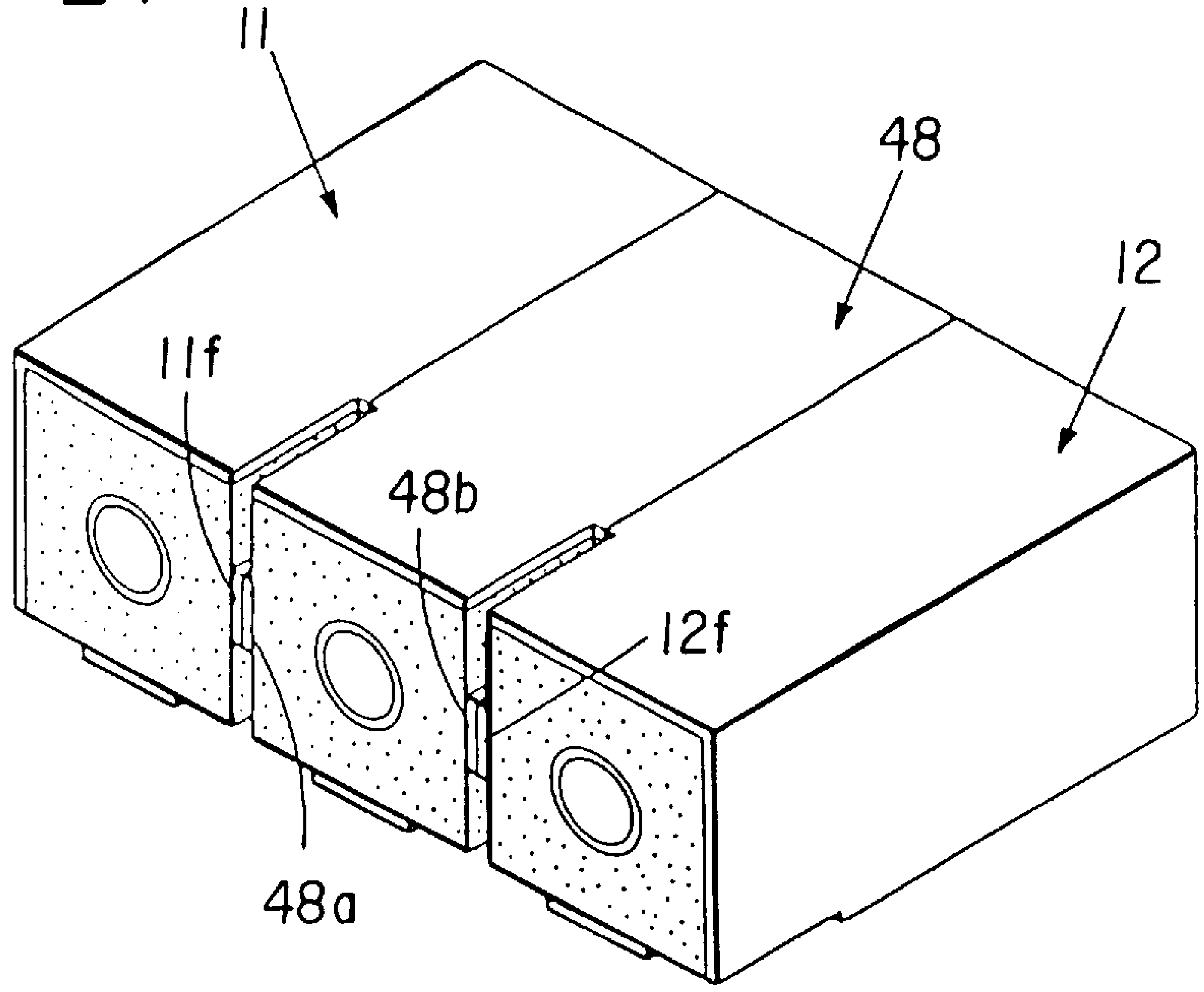


FIG. 25

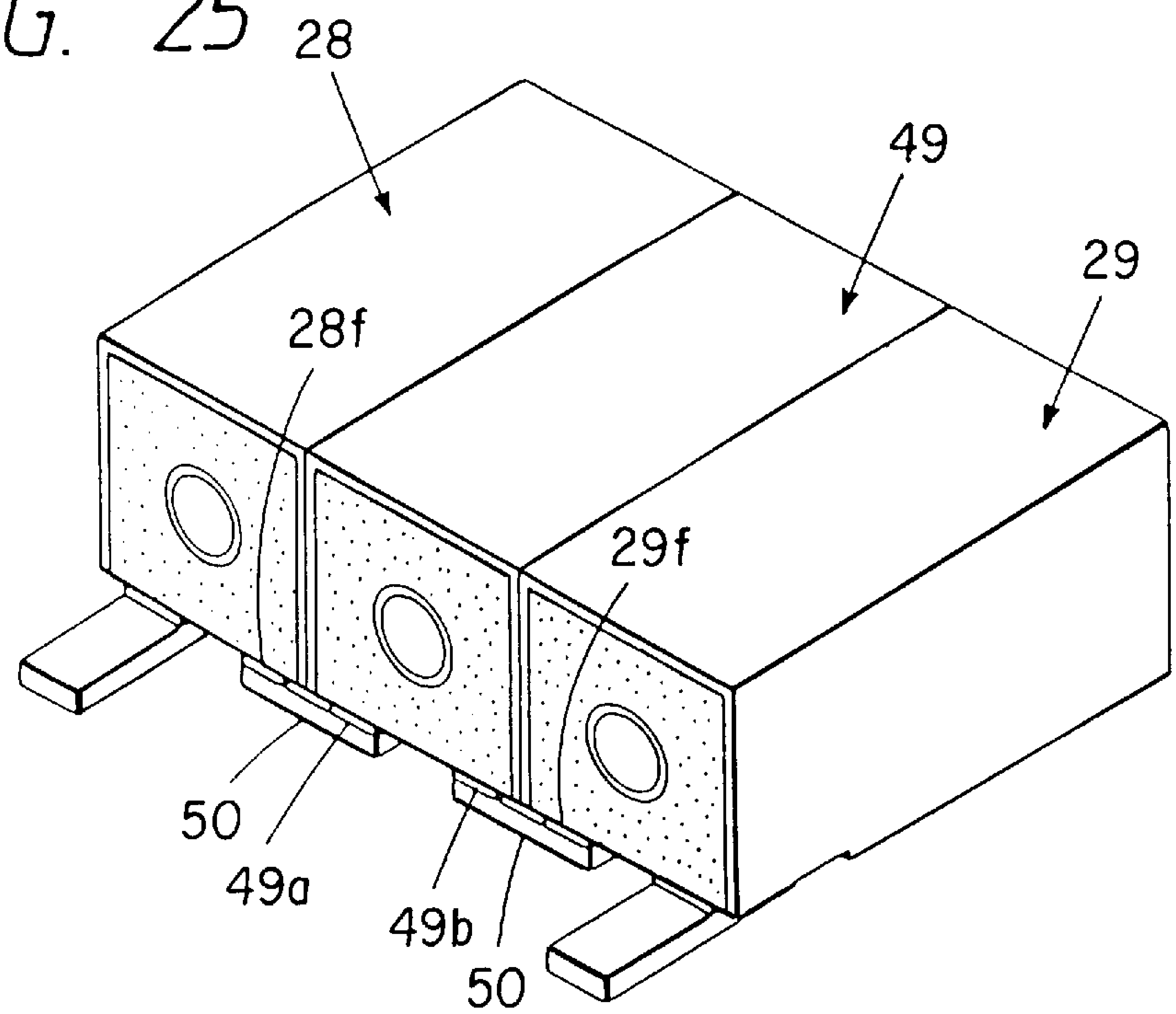


FIG. 26

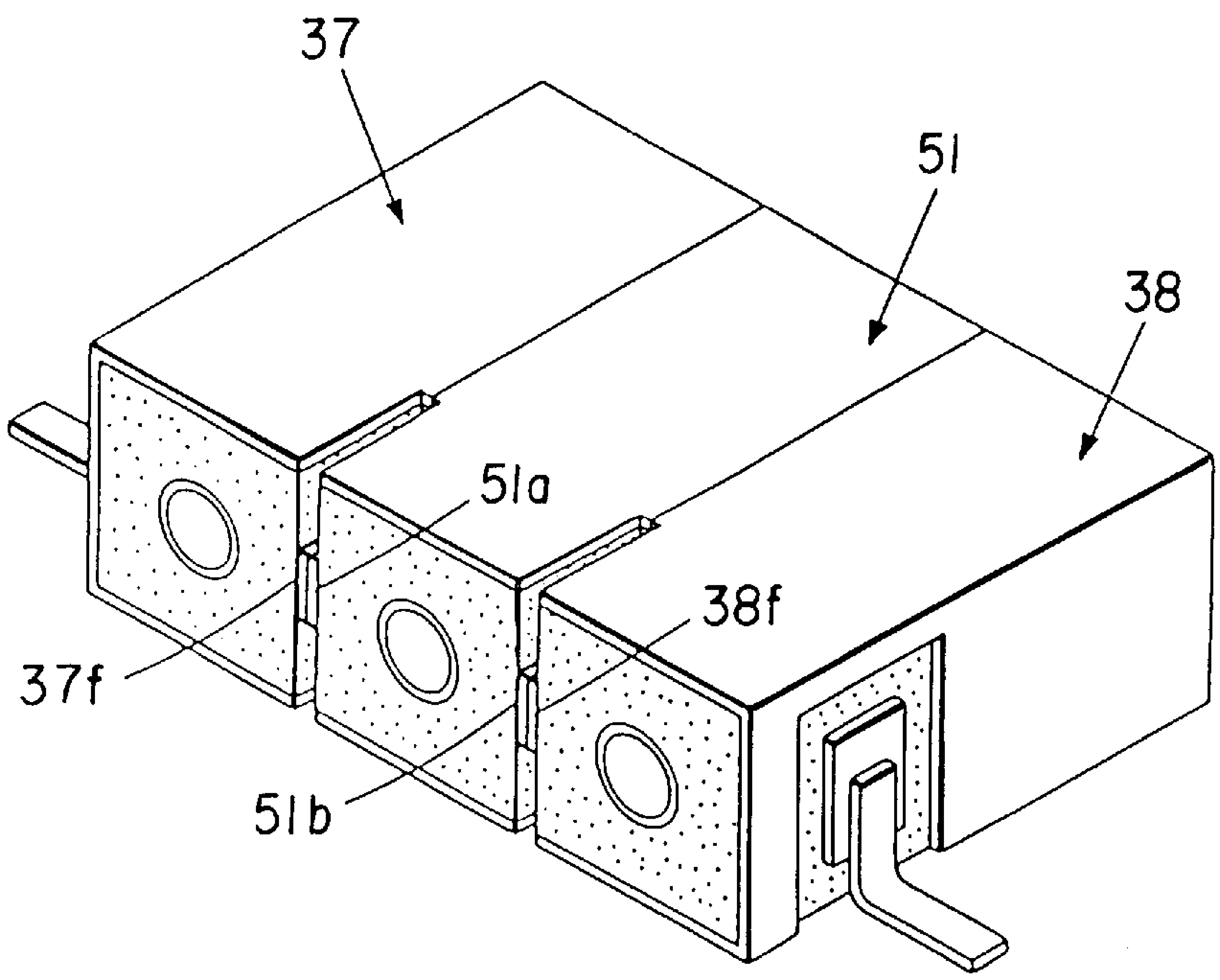


FIG. 27
PRIOR ART

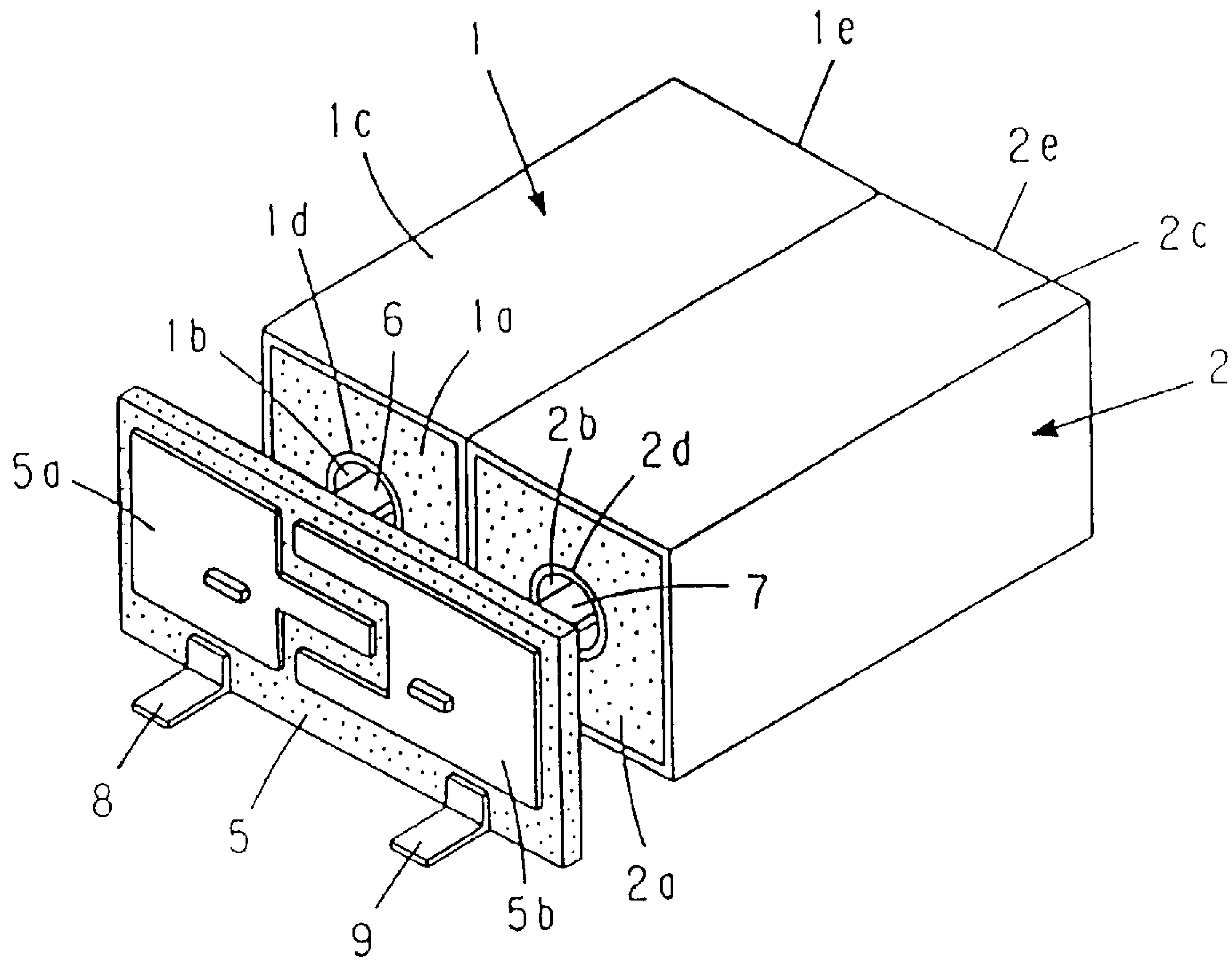


FIG. 28A
PRIOR ART

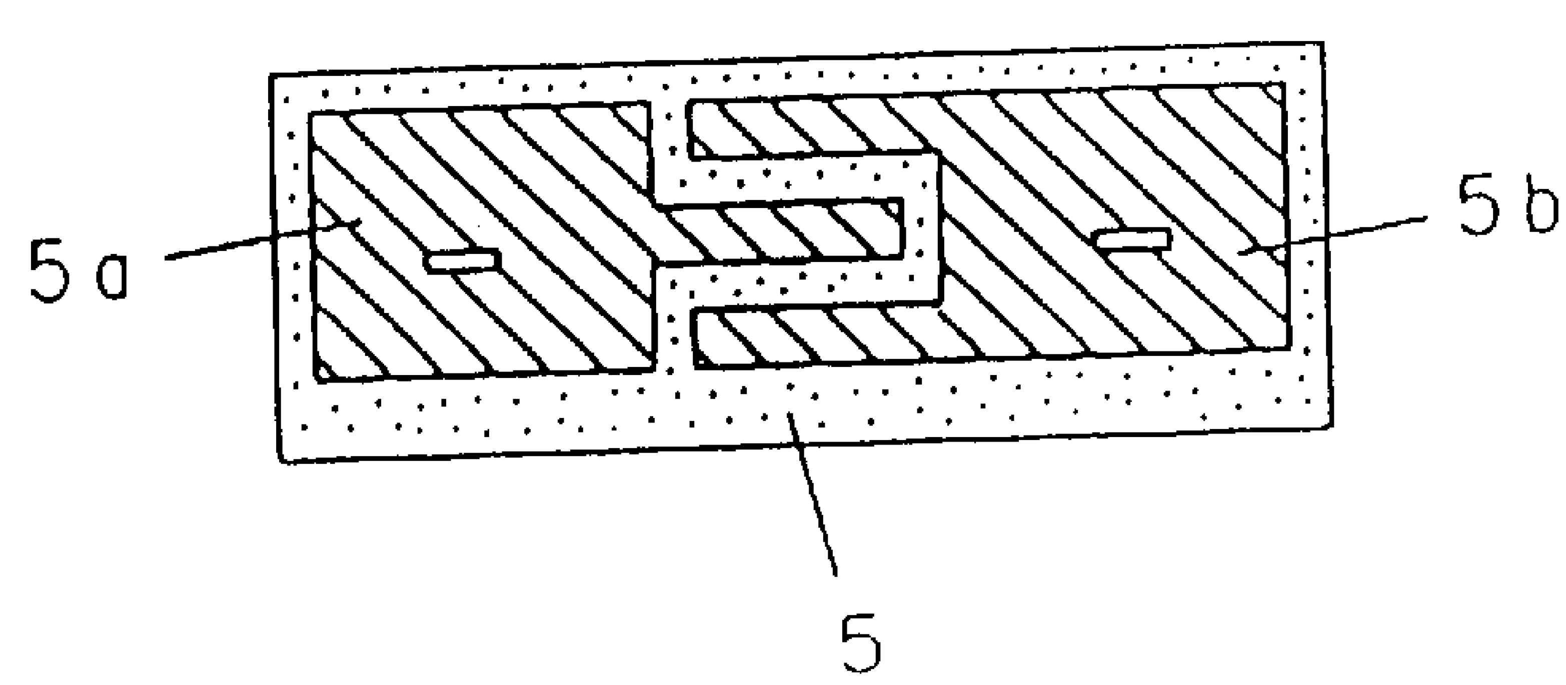


FIG. 28B
PRIOR ART

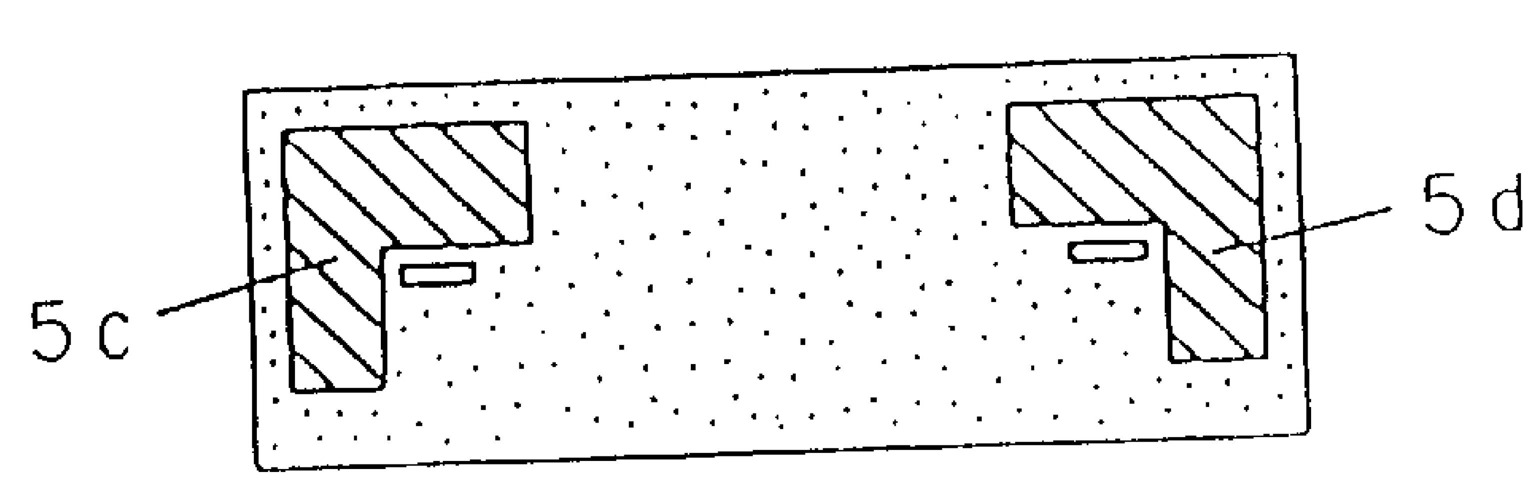
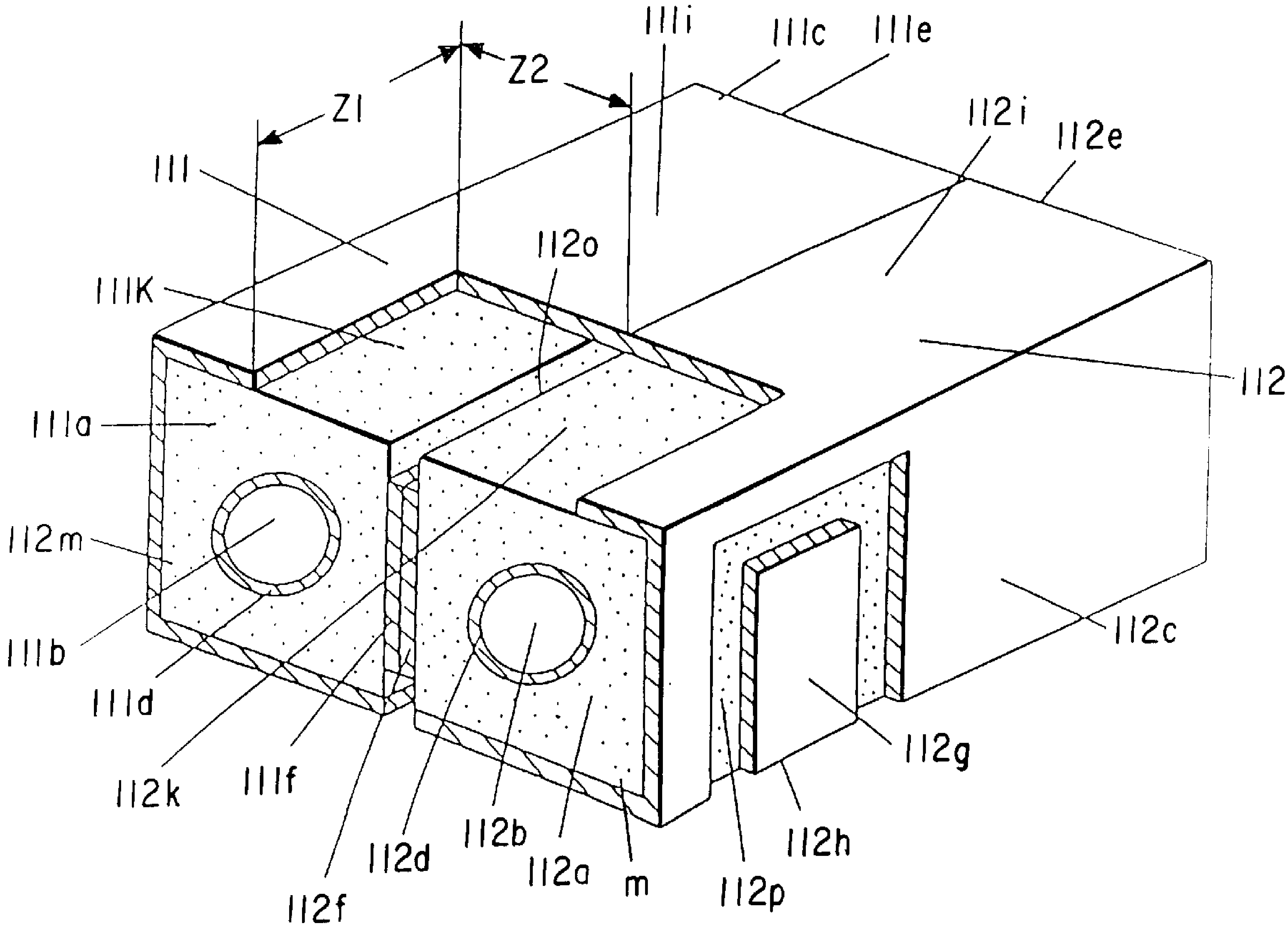


FIG. 29



Z1
Z2
111i
111c
111e
112i
112e
111
112o
111K
112
111a
112m
111b
111d
112k
111f
112f
112d
112b
112a
m
112p
112h
112g
112c

FIG. 30

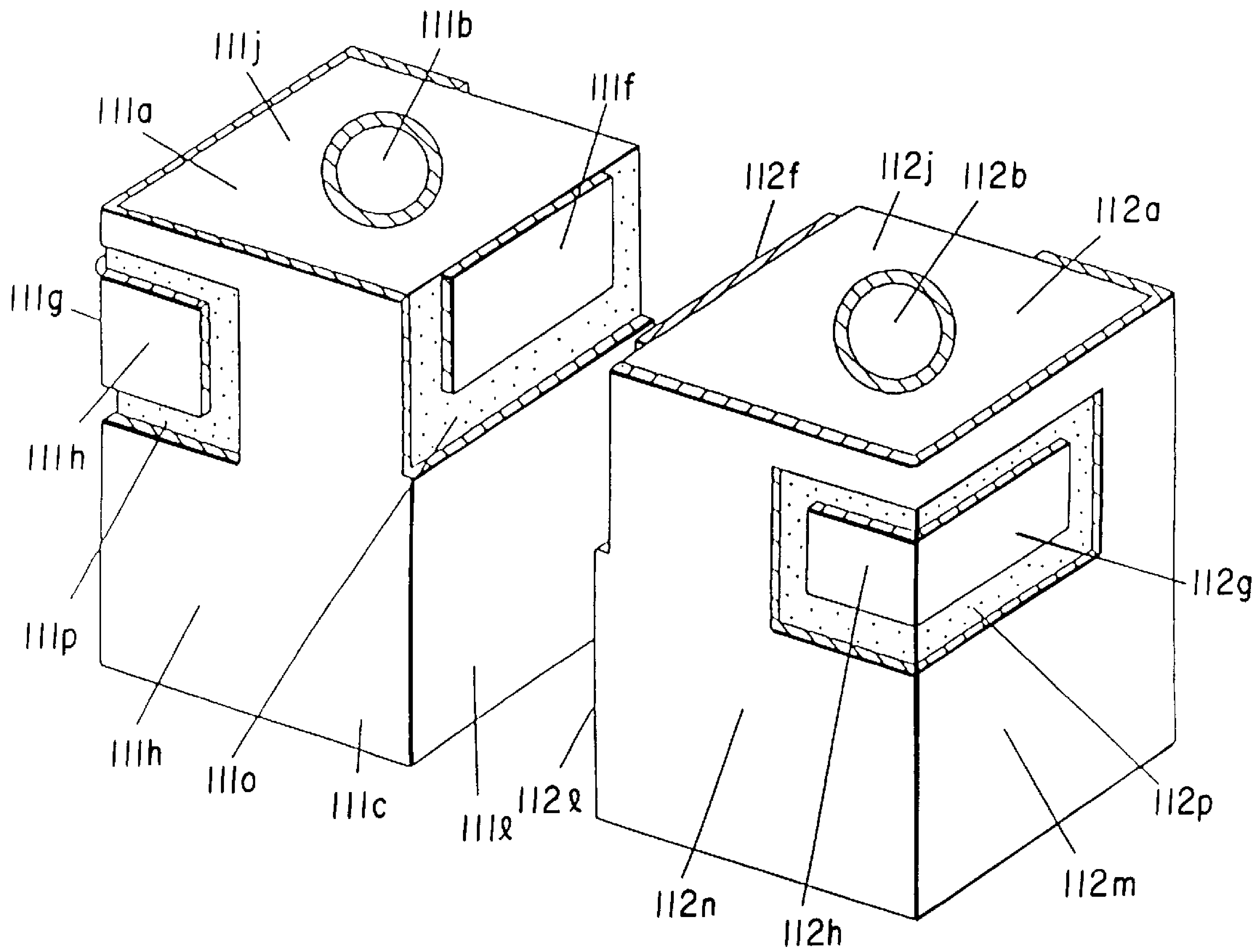

111j
111b
111a
111f
112f
112j
112b
112a
111g
111h
112g
111p
111h
111o
111c
111ℓ
112ℓ
112p
112m
112n
112h

FIG. 31

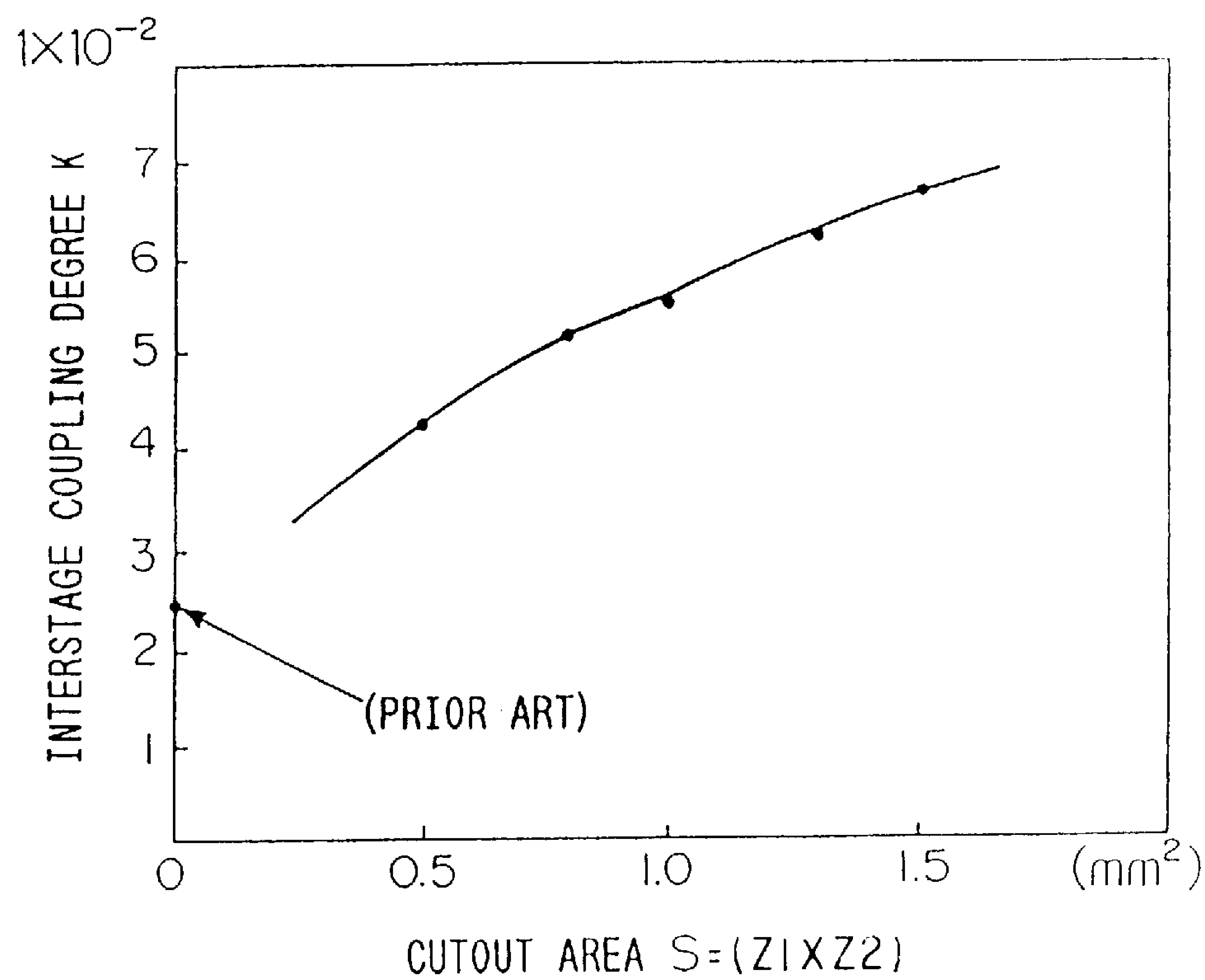

1×10⁻²
INTERSTAGE COUPLING DEGREE K
7
6
5
4
3
2
1
(PRIOR ART)
0
0.5
1.0
1.5
(mm²)
CUTOUT AREA S=(Z1XZ2)

FIG. 32

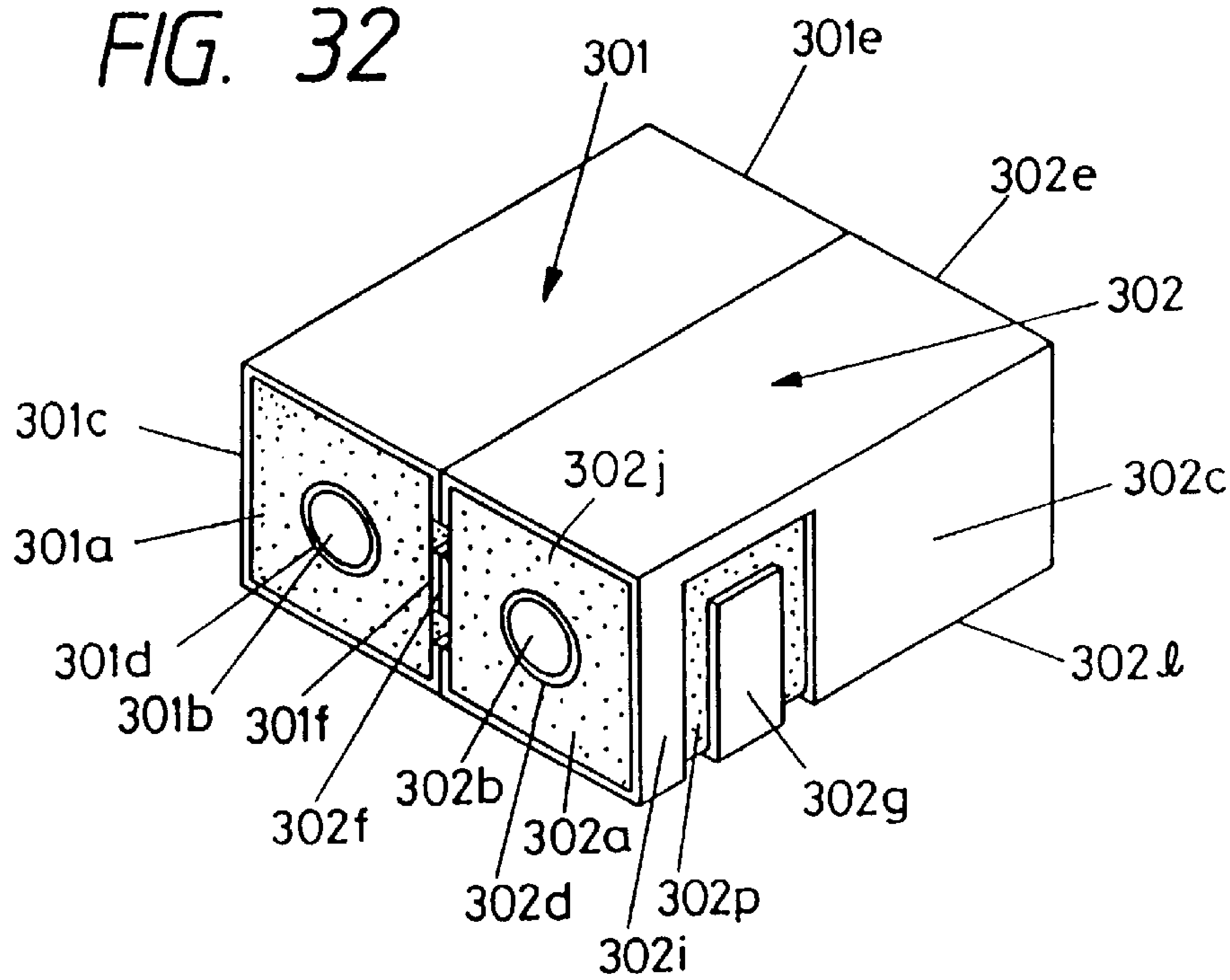
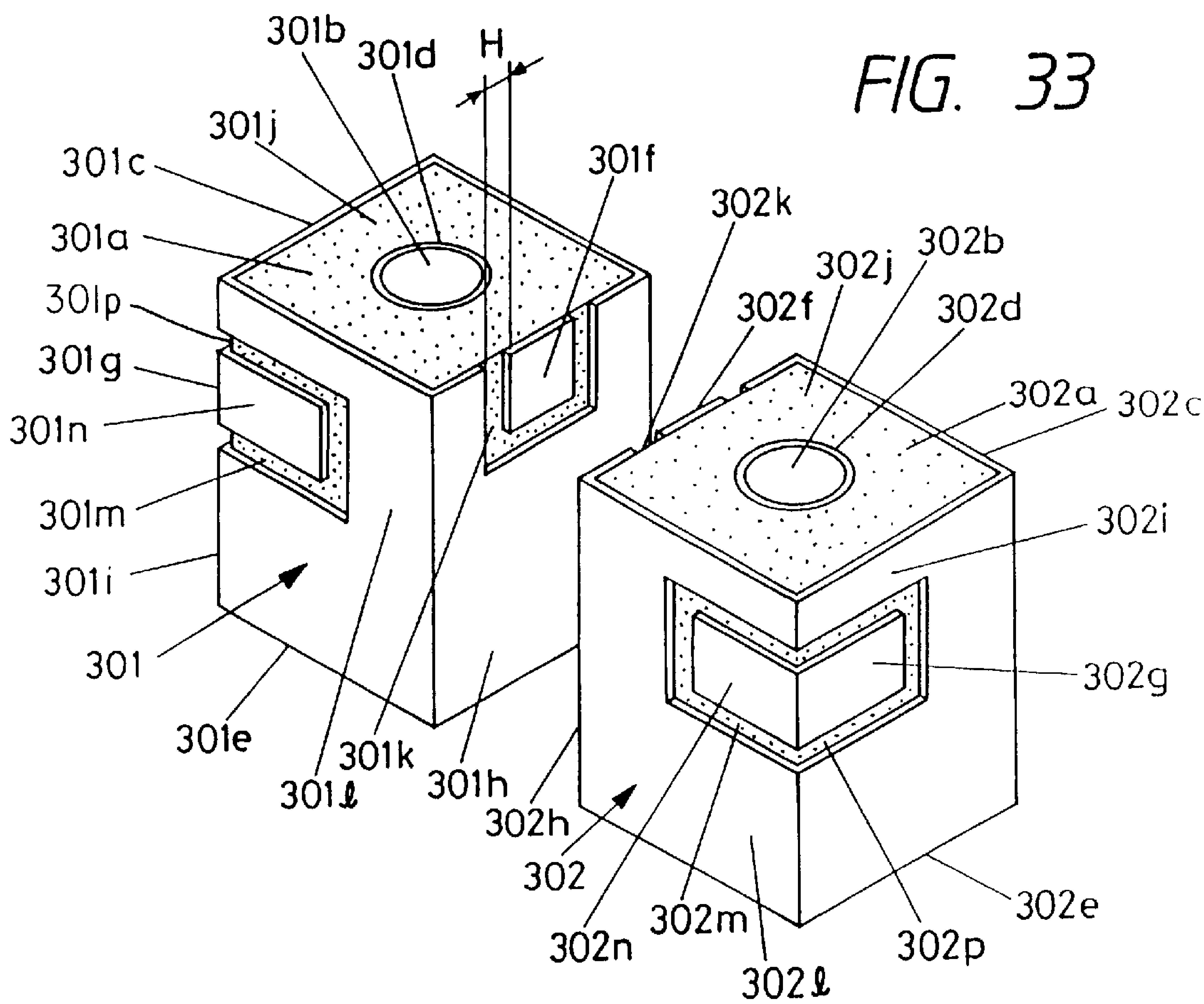

301
301e
302e
302
301c
302j
302c
301a
302ℓ
301d
301b
301f
302g
302b
302f
302a
302p
302d
302i

FIG. 33


301b
301d
H
301j
301c
301f
302k
301a
302j
302b
301p
302f
302d
301g
302a
302c
301n
301m
302i
301i
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301ℓ
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302n
302ℓ

FIG. 34

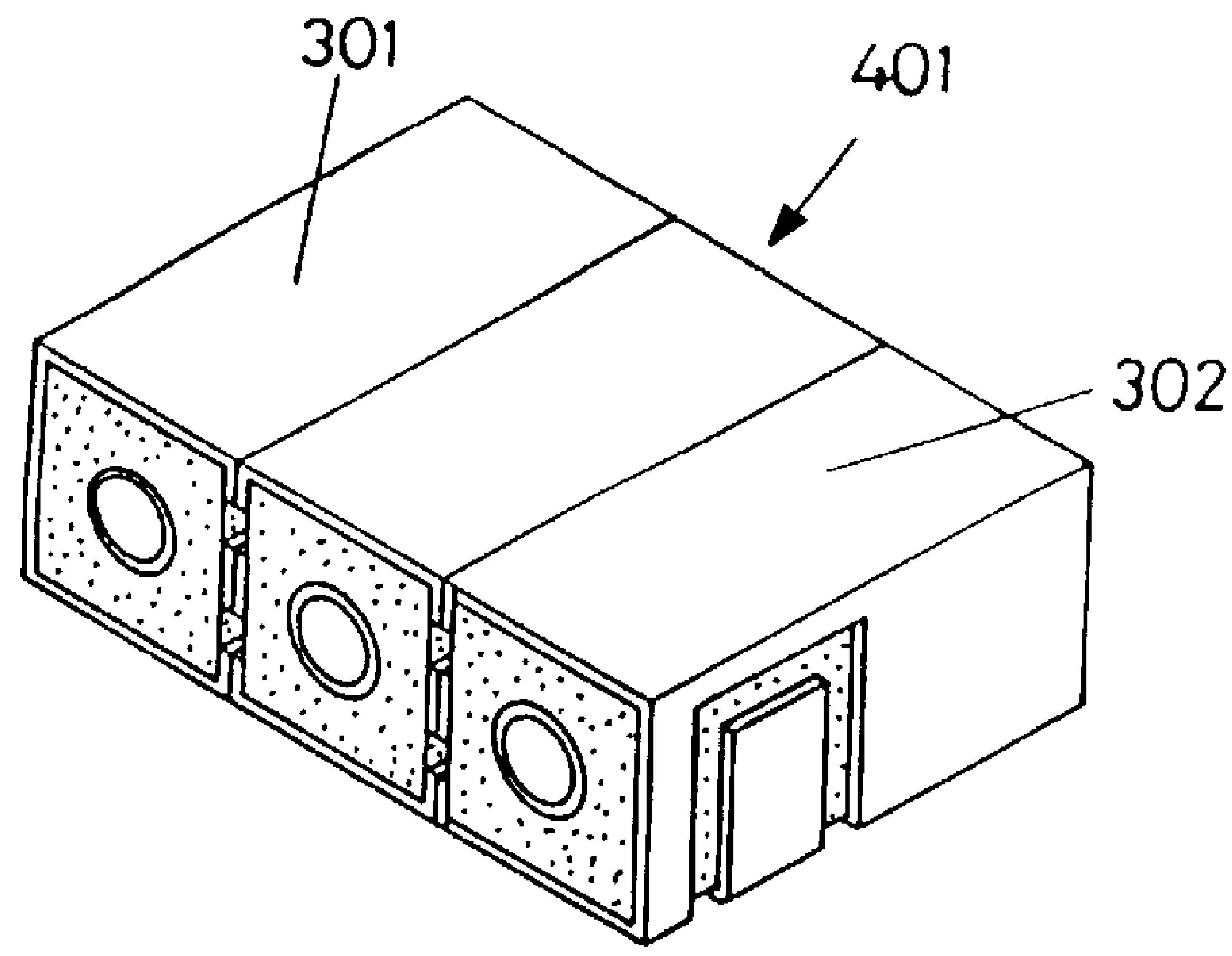


FIG. 35

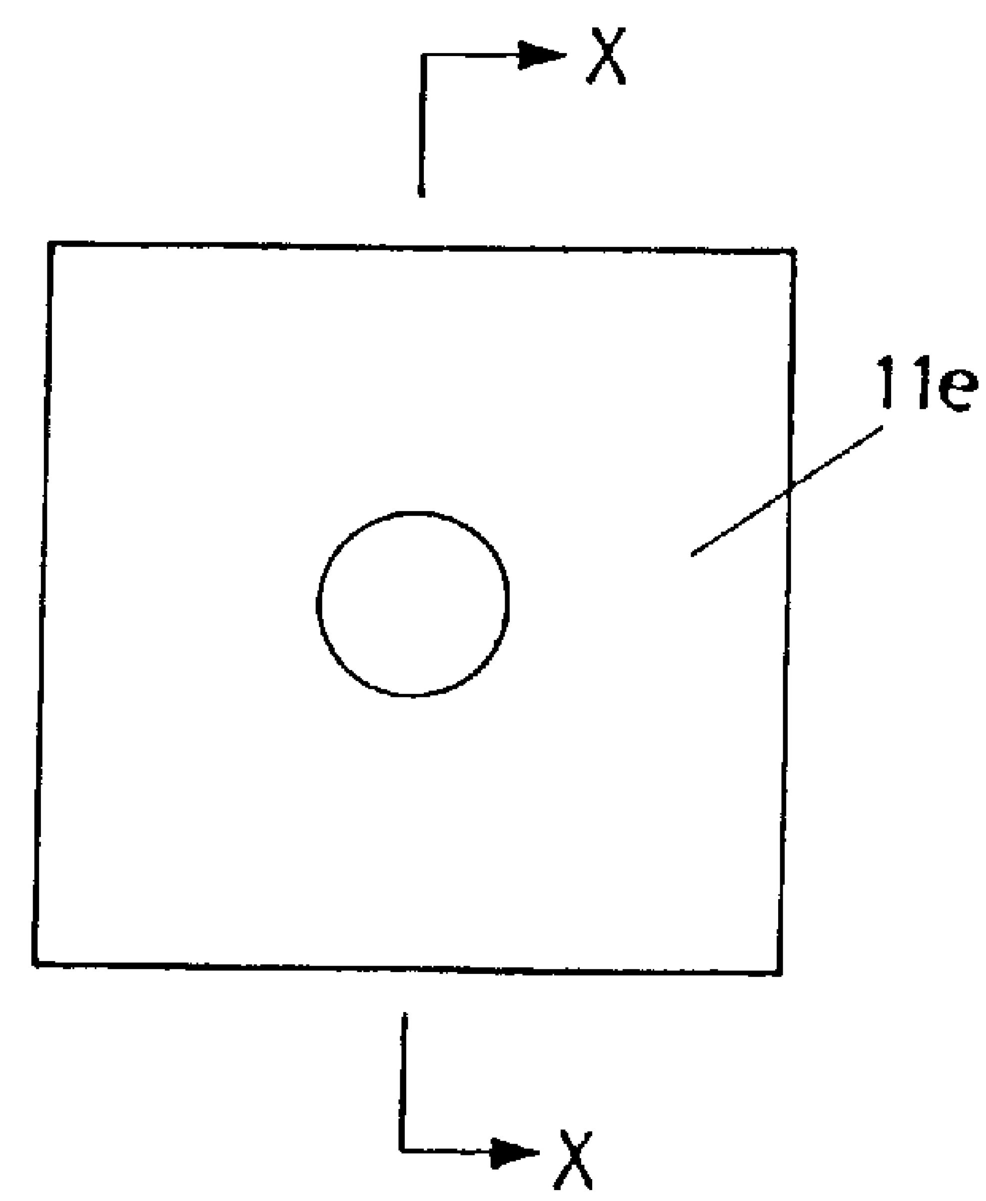
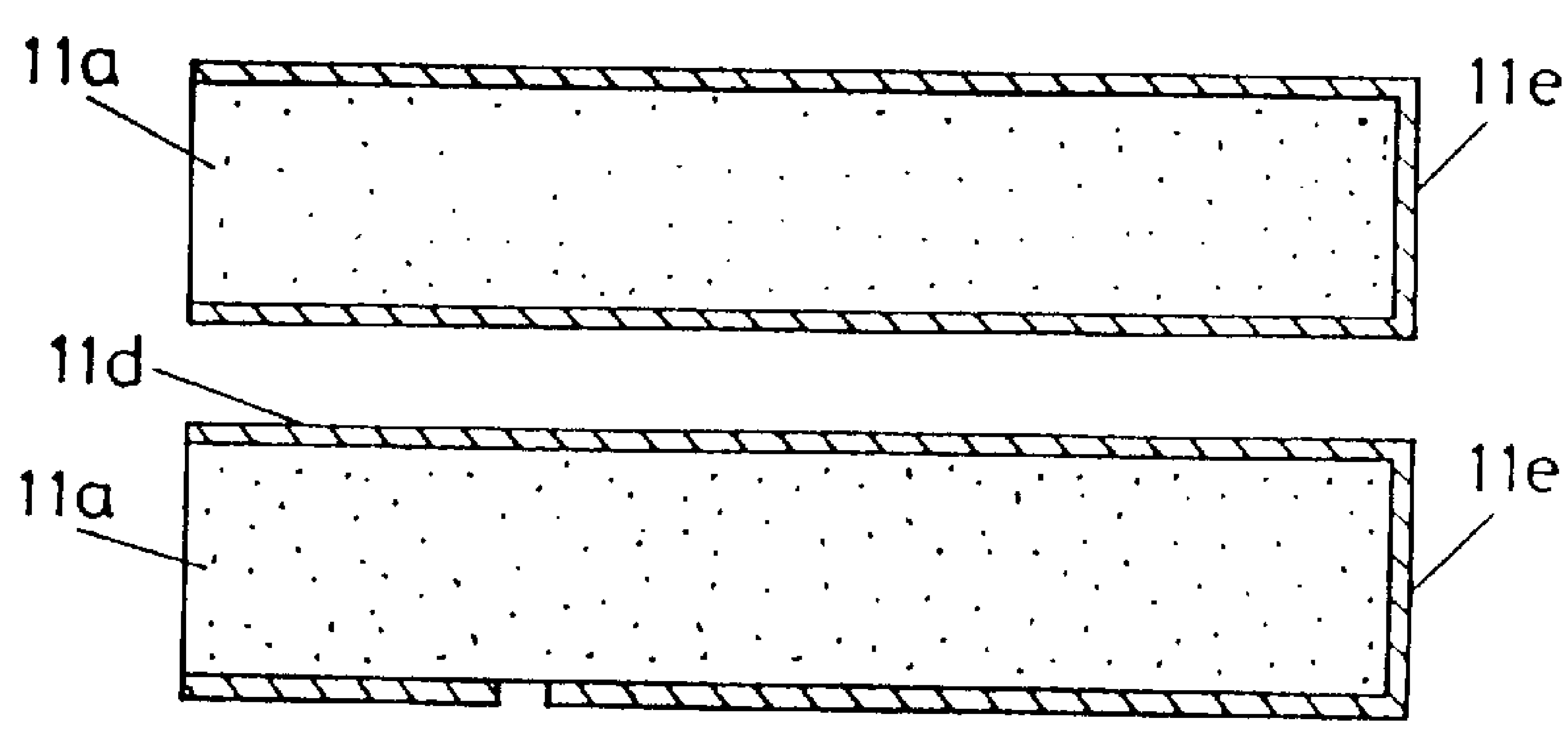


FIG. 36



DIELECTRIC FILTER

This is a Division of application Ser. No. 08/202,073 filed Feb. 25, 1994, now issued as U.S. Pat. No. 5,499,004.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a dielectric filter installed on a communication apparatus, such as a portable telephone and a wireless telephone.

2. Description of the Prior Art

A conventional dielectric filter will be explained hereinafter.

FIG. **27** is a perspective view showing a conventional dielectric filter. Reference numerals **1** and **2** represent respective dielectric resonators comprising: dielectric base bodies **1***a*, **2***a* made of dielectric material, with respective centrally axially extending through holes **1***b*, **2***b*; respective outer conductors **1***c*, **2***c* surrounding respective outer surfaces of the dielectric base bodies **1***a*, **2***a*; respective inner conductors **1***d*, **2***d* provided along respective inner surfaces of the through holes **1***b*, **2***b*; and respective connecting conductors **1***e* and **2***e* connecting the outer conductors **1***c*, **2***c* and the inner conductors **1***d*, **2***d*. A reference numeral **5** represents a coupling substrate **5** comprising conductors **5***a*, **5***b* (as shown in FIG. **28**A) and **5***c*, **5***d* (as shown in FIG. **28**B) formed on a dielectric substrate (alumina substrate or the like). This connecting substrate **5** realizes input/output coupling capacitances (one is between conductors **5***a* and **5***c*, the other between conductors **5***b* and **5***d*) and an interstage coupling capacitance (between **5***a* and **5***b*). FIG. **28**(A) is a detailed front view showing the coupling substrate **5** of the conventional dielectric filter, and FIG. **28**(B) is a detailed rear view showing the coupling substrate **5** of the conventional dielectric filter. Reference numerals **6** and **7** represent central conductors connecting the inner conductors **1***d*, **2***d* and the coupling substrate **5** electrically and mechanically. Reference numerals **8** and **9** represent input and output terminals which are connected to the conductors **5***c*, **5***d* of the coupling substrate **5** electrically and mechanically by means of solder or the like.

However, this kind of conventional dielectric filter inherently requires numerous components, such as the coupling substrate **5**, central conductors **6**, **7**, and input/output terminals **8**, **9**. This encounters with the difficulty in reducing the size of a dielectric filter. Furthermore, mass-productivity is not good due to a large number of parts and time-consuming production process.

SUMMARY OF THE INVENTION

Accordingly, in view of above-described problems encountered in the prior art, an object of the present invention is to provide a dielectric filter capable of reducing the size and the number of parts and having excellent mass productivity.

In order to accomplish the above object, a first aspect of the invention provides a dielectric filter comprising: at least two dielectric resonators each including: a respective dielectric base body including corresponding first, second, third and fourth side surfaces and first and second end surfaces, wherein a respective through hole is provided from the first end surface to the second end surface along a central axis of the corresponding dielectric base body to define a respective inner surface thereof; a respective outer conductor located on and partially covering the first, second, third and fourth

side surfaces of the corresponding dielectric base body, wherein the outer conductor provides an uncovered portion of the first side surface that extends across a width of the respective first side surface and is adjacent to the corresponding first end surface, uncovered portions of the respective second and third side surfaces that are adjacent to each other and bounded by the corresponding outer conductor in three directions, and uncovered portion of the respective fourth side surface that is adjacent to the uncovered portion of the corresponding first side surface and the corresponding first end surface and is separated from the corresponding third side surface by the respective outer conductor; a respective inner conductor located on the inner surface of the corresponding dielectric base body; a respective connection conductor located on the second end surface of the corresponding dielectric base body, wherein the respective connection conductor connects the inner conductor to the outer conductor on the corresponding dielectric base body; a respective interstage coupling electrode located on the uncovered portion of the corresponding first side surface, wherein a respective area of the uncovered portion of the corresponding first side surface extends in at least three directions from the respective interstage coupling electrode and separates the interstage coupling electrode from the corresponding outer conductor; and a respective input/output coupling electrode located on the uncovered portion of the second and third side surfaces of the corresponding dielectric base body, wherein respective areas of the uncovered portions of the corresponding second and third side surfaces extend in three directions from the input/output coupling electrode and separate the respective input/output coupling electrode from the corresponding outer conductor; wherein the respective dielectric resonators are connected with each other in such a manner that the outer conductor of a first one of the dielectric resonators is electrically connected to the outer conductor of a second one of the dielectric resonators.

In accordance with a second aspect of the invention, the interstage coupling electrode of the first one of the dielectric resonators is electrically connected to the interstage coupling electrode of the second one of the dielectric resonators with respect to the first aspect of the invention discussed above.

In accordance with a third aspect of the invention, a dielectric filter is provided that comprises: at least two dielectric resonators each including: a respective dielectric base body including corresponding first, second, third and fourth side surfaces and first and second end surfaces, wherein a respective through hole is provided from the first end surface to the second end surface along a central axis of the corresponding dielectric base body to define a respective inner surface thereof; a respective outer conductor located on the first, second, third and fourth side surfaces of the corresponding dielectric base body, wherein the respective outer conductor covers the fourth side surface and leaves an uncovered portion of the first side surface that is adjacent to the first end surface and bounded in three directions by the corresponding outer conductor, and uncovered portions of the respective second and third side surfaces that are adjacent to each other and bounded by the corresponding outer conductor in three directions; a respective inner conductor located on the inner surface of the corresponding dielectric base body; a respective connection conductor located on the second end surface of the corresponding dielectric base body, wherein the respective connection conductor connects the inner conductor to the outer conductor on the corresponding dielectric base body; a respective interstage coupling electrode located on the uncovered portion of the corresponding first side surface, wherein a respective area of the uncovered portion of the corresponding first side surface extends in three directions from the respective interstage coupling electrode and separates the respective interstage coupling electrode from the corresponding outer conductor; and a respective input/output coupling electrode located on the uncovered portion of the second and third side surfaces of the corresponding dielectric body, wherein a respective area of the uncovered portions of the corresponding second and third side surfaces extend in three directions from the respective input/output coupling electrode and separate the respective input/output coupling electrode from the corresponding outer conductor; wherein the respective dielectric resonators are connected with each other in such a manner that the outer conductor of a first one of the dielectric resonators is electrically connected to the outer conductor of a second one of the dielectric resonators.

In accordance with a fourth aspect of the invention, the interstage coupling electrode of the first one of the dielectric resonators is electrically connected to the interstage coupling electrode of the second one of the dielectric resonators with respect to the third aspect of the invention discussed above.

The above and other objects, features and advantages of the present invention will become more apparent from the following detailed description which is to be read in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view showing a dielectric filter in accordance with a first embodiment of the present invention;

FIG. **2** is an exploded perspective view showing the dielectric filter in accordance with the first embodiment of the present invention;

FIG. **3** is a circuit diagram showing an equivalent circuit of the dielectric filter in accordance with the first embodiment of the present invention;

FIG. **4** is a perspective view showing the dielectric filter mounted on a substrate in accordance with the first embodiment of the present invention;

FIG. **5** is a graph showing comparison of damping characteristics between the first embodiment and a prior art filter;

FIG. **6** is a perspective view showing a process of one manufacturing method of a dielectric resonator in accordance with the first embodiment of the present invention;

FIG. **7** is a perspective view showing another process of the one manufacturing method of the dielectric resonator in accordance with the first embodiment of the present invention;

FIG. **8** is a perspective view showing still another process of the one manufacturing method of the dielectric resonator in accordance with the first embodiment of the present invention;

FIG. **9** is a perspective view showing still another process of the one manufacturing method of the dielectric resonator in accordance with the first embodiment of the present invention;

FIG. **10** is a perspective view showing a modified embodiment of the first embodiment of the present invention;

FIG. **11** is an exploded perspective view showing the modified embodiment of the first embodiment of the present invention;

FIG. **12** is a perspective view showing a dielectric filter in accordance with a second embodiment of the present invention;

FIG. **13** is an exploded perspective view showing the dielectric filter in accordance with the second embodiment of the present invention;

FIG. **14** is a perspective view showing the dielectric filter mounted on a substrate in accordance with the second embodiment of the present invention;

FIG. **15** is a perspective view showing a modified embodiment of the second embodiment of the present invention;

FIG. **16** is an exploded perspective view showing the modified embodiment of the second embodiment of the present invention;

FIG. **17** is a perspective view showing a dielectric filter in accordance with a third embodiment of the present invention;

FIG. **18** is an exploded perspective view showing the dielectric filter in accordance with the third embodiment of the present invention;

FIG. **19** is a perspective view showing the dielectric filter mounted on a substrate in accordance with the third embodiment of the present invention;

FIG. **20** is a perspective view showing the dielectric filter mounted on a substrate in accordance with the third embodiment of the present invention;

FIG. **21** is a graph showing the comparison of damping characteristics outside the band with respect to frequencies between the first embodiment (represented by curve B) and third embodiment (represented by curve A);

FIG. **22** is a perspective view showing a dielectric filter in accordance with a fourth embodiment of the present invention;

FIG. **23** is an exploded perspective view showing the dielectric filter in accordance with the fourth embodiment of the present invention;

FIG. **24** is a perspective view showing a modified dielectric filter of the first embodiment, wherein three dielectric resonators are included;

FIG. **25** is a perspective view showing a modified dielectric filter of the second embodiment, wherein three dielectric resonators are included;

FIG. **26** is a perspective view showing a modified dielectric filter of the third embodiment, wherein three dielectric resonators are included;

FIG. **27** is a perspective view showing a conventional dielectric filter;

FIG. **28(A)** is a front view showing a coupling substrate of the conventional dielectric filter;

FIG. **28(B)** is a rear view showing a coupling substrate of the conventional dielectric filter;

FIG. **29** is a perspective view showing a dielectric filter in accordance with a fifth embodiment of the present invention;

FIG. **30** is an exploded perspective view showing the dielectric filter in accordance with the fifth embodiment of the present invention;

FIG. **31** is a graph showing a relationship between an area S of a cutout portion and an interstage coupling degree K in accordance with the fifth embodiment of the present invention;

FIG. **32** is a perspective view showing a dielectric filter in accordance with a sixth embodiment of the present invention;

FIG. **33** is an exploded perspective view showing the dielectric filter in accordance with the sixth embodiment of the present invention;

FIG. **34** is a perspective view showing a modified dielectric filter of the sixth embodiment, wherein three dielectric resonators are included;

FIG. **35** is a rear view showing one dielectric resonator of the dielectric filter in accordance with the first embodiment of the present invention; and

FIG. **36** is a cross-sectional view showing the dielectric resonator, taken along a line X—X of FIG. **35**.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Hereinafter, preferred embodiments of the present invention will be explained in detail with reference to accompanying drawings.

First Embodiment

FIGS. **1** and **2** are perspective and exploded views showing a dielectric filter of the first embodiment of the present invention. In FIGS. **1** and **2**, reference numerals **11** and **12** represent dielectric resonators. Hereinafter, taking the dielectric resonator **11** of these two dielectric resonators, a construction of the dielectric resonator will be explained. A dielectric base body **11***a* made of dielectric material, such as $BaO—TiO_2—Nd_2O_3$, $BaO—TiO_2$, $ZrO_2—SnO_2—TiO_2$, $BaO—Sm_2O_3—TiO_2$, is formed with a centrally axially extending through hole **11***b*. The dielectric base body **11***a* has an outer configuration of rectangular parallelepiped having a square cross section, while the through hole **11***b* has a circular cross section.

An outer conductors **11***c* is provided on the outer side surface of the dielectric base body **11***a* so as to surround it. An inner conductor **11***d* is provided along the inner side surface of the through hole **11***b*. The outer conductor **11***c* and the inner conductor **11***d* are connected with each other via a connecting conductor **11***e*. This connecting conductor **11***e* is provided on a closed end surface, i.e. a base of the rectangular parallelepiped, of the dielectric base body **11***a* as shown in FIGS. **35** and **36**. Of four outer side surfaces of the dielectric base body **11***a*, two side surfaces **11***i* and **11***h* are partly cut off so that the dielectric base body **11***a* is exposed near the open end **11***j*. Namely, a cutout **11***k* (see FIG. **2**) of the outer conductor **11***c* bridging both the two side surfaces **11***i* and **11***h* is formed near the open end of the dielectric base body **11***a*.

Furthermore, an interstage coupling electrode **11***f* is provided within the region of the cutout **11***k* on the outer side surface **11***i*, so that this interstage coupling electrode **11***f* does not contact with other conductors. In the same manner, an input/output coupling electrode **11***g* is provided within the region of the cutout **11***k* on the outer side surface **11***h*, so that this input/output coupling electrode **11***g* does not contact with other conductors.

Likewise, the other dielectric resonator **12** comprises: a dielectric base body **12***a*, a through hole **12***b*, an outer conductor **12***c*, an inner conductor **12***d*, a connecting conductor **12***e*, an interstage coupling electrode **12***f*, an input/output coupling electrode **12***g*, outer side surfaces **12***h* and **12***i*, an open end **12***j*, and a cutout **12***k* (see FIG. **2**).

The like parts between the dielectric resonators **11** and **12** are denoted by the same reference alphabet throughout views. (For example, the dielectric base body **11***a* is substantially identical with the dielectric base body **12***a*) However, as apparent from FIG. **2**, the relationship between the dielectric resonator **11** and the dielectric resonator **12** are mirror symmetry. Therefore, in production of each dielectric resonator, it is necessary to pay attention to the positional relationship between the electrodes **11***f*, **11***g* and **12***f*, **12***g*.

More specifically, the dielectric resonator **11** and the dielectric resonator **12** are connected by means of, for example, cream solder in such a manner that the electrodes **11***f* and **12***f* confront and contact with each other and the electrodes **11***g* and **12***g* are placed on the same plane.

Furthermore, the outer conductors **11***c*, **12***c*, inner conductors **11***d*, **12***d*, connecting conductors **11***e*, **12***e*, electrodes **11***f*, **12***f*, and electrodes **11***g*, **12***g* (hereinafter, these components respectively are referred to as conductor film) are basically thin film made of conductive material such as copper and silver. The thickness of the film is approximately 5 μm. Although the conductor film is a single layer in this embodiment, it is needless to say that two or more layer structure can be allowed. Regarding the film thickness of approximately 5 μm, this value should be adequately changed depending on the condition of the dielectric filter in service.

Although the electrodes **11***g*, **12***g* and **11***f*, **12***f* are rectangular in this first embodiment, the configuration of these electrodes **11***g*, **12***g* and **11***f*, **12***f* can be any other shape, such as circle, ellipse, and polygon.

FIG. **3** is a circuit diagram showing an equivalent circuit of the dielectric filter in accordance with the first embodiment of the present invention depicted in FIGS. **1**, **2**. In FIG. **3**, a reference numeral **13** represents an equivalent circuit of the dielectric resonator **11** and a reference numeral **14** represents an equivalent circuit of the other dielectric resonator **12** depicted in FIGS. **1**, **2**. C**1** represents a capacitance between the electrode **11***g* and the inner conductor **11***d*, and C**3** represents a capacitance between the electrode **12***g* and the inner conductor **12***d*. C**2** represents a composite capacitance of two capacitances—one is a capacitance between the electrodes **11***f* and **11***d*, and the other is a capacitance between the electrodes **12***f* and **12***d*. As understood from this equivalent circuit, the dielectric filter of the present embodiment has substantially the same circuit configuration as the conventional dielectric filter. Nevertheless, the structure of this embodiment is very simplified and compact when compared with that of the conventional one. In more detail, this embodiment no longer requires the central conductor and the dielectric substrate of the conventional dielectric filter. This results in 50% reduction of overall size.

FIG. **4** is a perspective view showing the dielectric filter mounted on a substrate in accordance with the first embodiment of the present invention. In FIG. **4**, a reference numeral **15** represents a printed circuit board constituted by insulating material, such as glass . epoxy resin. Reference numerals **16** and **17** represent input/output pathways formed on the printed circuit board **15**. Similarly, a reference numeral **18** represents a grounded pathway formed on the printed circuit board **15**. The electrode **11***g* of the dielectric resonator **11** is connected onto the input/output pathway **16** by a solder **19**, and the electrode **12***g* of the dielectric resonator **12** is connected onto the input/output pathway **17** by a solder **20**. Furthermore, the outer conductors **11***c* and **12***c* of the dielectric resonators **11** and **12** are connected onto the grounded pathway **18** by solder **21**. The input/output pathways **16**, **17** and the grounded pathway **18** are formed by coating conductive paste, such as Ag paste, on the printed circuit board **15** in a predetermined pattern and then fixing it by printing.

FIG. **5** is a graph showing comparison of damping characteristics between the first embodiment and the prior art. In FIG. **5**, a line A represents a characteristic curve of the first embodiment and B represents a characteristic curve of the prior art filter. As apparent from FIG. **5**, the characteristic curve A of the first embodiment has two extreme values A**1** and A**2** at low and high frequencies. This is because, as shown in the equivalent circuit of FIG. **3**, the interstage coupling causes a small amount of electromagnetic coupling M besides the coupling capacitance (C**1**, C**2**, C**3**). On the contrary, the characteristic curve B of the prior art does not generate the similar extreme values.

A manufacturing method of the above-described dielectric filter will be explained hereinafter.

First of all, starting materials (for example, BaO, TiO_2, Nd_2O_3 or the like) are blended at a predetermined ratio. Then, the blended material is mixed by using a mill or else. Next, the mixed material is granulated by using a spray dryer or the like, so as to adjust the particle size and add binder. Subsequently, the granulated material is pelletized by a dry press so as to be formed into a predetermined shape. In turn, the pelletized material is sintered in a kiln at the temperature of 1300° C. to 1400° C. Thus, the dielectric base body **11***a* of cylindrical shape shown in FIG. **6** is obtained. Then, the conductor film is formed on the dielectric base body **11***a*. There are various method for forming the conductor film, several of which will be explained below.

A first method is applied in a case where copper is used as a material constituting the conductor film. The surface of the dielectric base body **11***a* is roughened by a barrelling machine or a blast device. Thereafter, the dielectric base body **11***a* is processed by etching until the roughness of the surface of the dielectric base body **11***a* becomes 5 μm to 9 μm. Etchant to be used in this etching will be, for example, HF—HNO_2 series. Subsequently, all the surface of the dielectric base body **11***a* is processed by stannous chloride or the like to give sensitivity. Then, palladium qualifying as catalytic metal is attached on all the surface of the dielectric base body **11***a*. Next, as shown in FIG. **7**, a resist film **23** is formed partially on the dielectric base body **11***a*. Namely, this resist film **23** defines a region on which no conductor film of the dielectric base body **11***a* is provided—a region becoming the cutout **11***k* or the open end **11***j* as depicted in FIG. **2**. In the formation of this resist film **23**, resist ink is coated on the dielectric base body **11***a* by the use of printing technology or else and then thus printed resist ink is dried until it hardens. Next, on thus manufactured dielectric base body **11***a*, there is formed a thin, first copper film by the electroless copper plating method. In this case, the first copper film is selectively formed only within a region where the resist film **23** is not provided. Subsequently, a second copper film is laminated on the first copper film by the electrolytic copper plating to form the conductor film whose thickness is approximately 5 μm. After the resist film **23** is removed by solvent or else, the dielectric resonator **11** (or **12**) shown in FIGS. **1** and **2** is manufactured. Although the above manufacturing method coats the resist ink on the predetermined portion of the dielectric base body **11***a* using the printing technology and then dries and hardens the resist ink, another manufacturing method will allow the use of a photosensitive resist as a resist. That is, after the catalytic metal, such as palladium, is attached on the dielectric base body **11***a*, photosensitive resist is coated on all the surface of the dielectric base body **11***a*. Then, a predetermined portion of the photosensitive resist is exposed and hardened. Thereafter, the portion not being hardened by exposure is washed away by developing solution. Then, the resist film **23** shown in FIG. **7** will be obtained.

Next, still another manufacturing method of the conductor film will be explained. First of all, a conductor film **24** is formed on all the surface of the dielectric base body **11***a* of FIG. **2** as shown in FIG. **8**. In this case, the conductor film **24** can be formed in the double-layer structure of copper as previously described. Furthermore, the conductor film **24** will be formed on the entire surface of the dielectric base body **11***a* by printing Ag paste on the entire surface of the dielectric base body **11***a*, drying this Ag paste, and applying a thermal treatment at the temperature of 800° C. to 900° C. In turn, a resist film **25** is formed on the conductor film **24** in a predetermined pattern as shown in FIG. **9**. The method of forming this resist film **25** is the same as in the previous method. The resist film **25** is formed to define the region where the conductors and electrodes are formed. Thereafter, the unnecessary portion of the conductor film **24** is removed by using the etching technology, such as chemical etching or dry etching. Thus, the dielectric resonator **11** (or **12**) shown in FIGS. **1** and **2** is manufactured.

Yet another manufacturing method (not shown) of the conductor film will be explained. After forming the conductor film **24** on the entire surface of the dielectric base body **11***a* as shown in FIG. **8**, cutting or laser machining is applied on the surface of the dielectric base body **11***a* to physically remove the predetermined portion of the surface. Thus, the dielectric resonator **11** (or **12**) shown in FIGS. **1** and **2** is manufactured.

The dielectric resonators **11** and **12** thus constructed are disposed in such a manner that the electrodes **11***f* and **12***f* confront with each other. Then, the outer conductors **11***i* and **12***i* are connected by means of cream solder or the like. Similarly, the electrodes **11***f* and **12***f* are connected by means of cream solder or the like as depicted in FIG. **2**.

Next, a modified embodiment of the first embodiment will be explained.

FIG. **10** is a perspective view showing the modified dielectric filter of the first embodiment of the present invention, and FIG. **11** is an exploded perspective view showing the modified dielectric filter of the first embodiment of the present invention.

In FIGS. **10** and **11**, reference numerals **26** and **27** represent dielectric resonators whose constructions are almost identical with those of FIGS. **1** and **2** except the configuration of the through hole. First of all, the dielectric resonator **26** will be explained. A reference numeral **26***a* represents a dielectric base body made of dielectric material. The outer configuration of the dielectric base body **26***a* is rectangular parallelepiped having a square cross section. Furthermore, a centrally axially extending through hole is formed in the dielectric base body **26***a*. The through hole consists of a large hole **26***b* and a small hole **26***c* (see FIG. **10**) extending centrally and axially and communicated with each other. The large hole **26***b* is positioned near the open end and has a square cross section, while the small hole **26***c* has a circular cross section.

Although the dielectric resonator of FIGS. **1** and **2** has the through hole of constant diameter extending from the open end to the connecting end—from one base to the other base of the rectangular parallelepiped—of the dielectric base body **11***a*, this modified embodiment is different from the embodiment of FIGS. **1** and **2** and characterized in that the through hole has a stepped portion. With this arrangement, an inner conductor **26***d* formed inside the large hole **26***b* can be made large. This means that it becomes possible to increase not only the input/output coupling capacitance between the electrode **26***e* and the inner conductor **26***d* but also the interstage coupling capacitance between the electrodes **26***f* and the inner conductor **26***d*; therefore, it becomes possible to manufacture a wide-band dielectric filter. In the same manner, the other dielectric resonator **27** includes a dielectric base body **27***a* with a centrally axially extending through hole consisting of a large square hole **27***b* and a small circular hole **27***c* (see FIG. **10**). By providing an inner conductor **27***d* inside this through hole, the input/output coupling capacitance between the electrodes **27***e* and **27***d* can be increased but the interstage coupling capacitance between the electrode **27***f* and the inner conductor **27***d* can be increased.

The remainder of the construction is substantially the same as that of FIGS. **1** and **2**.

Second Embodiment

FIGS. **12** and **13** are perspective and exploded views showing a dielectric filter of the second embodiment of the present invention. In FIGS. **12** and **13**, reference numerals **28** and **29** represent dielectric resonators. Hereinafter, taking the dielectric resonator **28** of these two dielectric resonators, a construction of the dielectric resonator will be explained. A dielectric base body **28***a* made of dielectric material, such as $BaO—TiO_2—Nd_2O_3$, $BaO—TiO_2$, $ZrO_2—SnO_2—TiO_2$, $BaO—Sm_2O_3—TiO_2$, is formed with a centrally axially extending through hole **28***b*. The dielectric base body **28***a* has an outer configuration of rectangular parallelepiped having a square cross section, while the through hole **28***b* has a circular cross section.

An outer conductors **28***c* is provided on the outer side surface of the dielectric base body **28***a* so as to surround it. An inner conductor **28***d* is provided along the inner side surface of the through hole **28***b*. The outer conductor **28***c* and the inner conductor **28***d* are connected with each other via a connecting conductor **28***e*. This connecting conductor **28***e* is provided on a closed end surface, i.e. a base of the rectangular parallelepiped, of the dielectric base body **28***a*, in the same manner as the connecting conductor **11***e* of the first embodiment explained with reference to FIGS. **35** and **36**. Of four outer side surfaces of the dielectric base body **28***a*, one side surface **28***h* is partly cut off so that the dielectric base body **28***a* is exposed near the open end **28***j*. Namely, a cutout **28***k* of the outer conductor **28***c* is formed near the open end **28***j* of the dielectric base body **28***a*. Furthermore, an interstage coupling electrode **28***f* is provided within the region of the cutout **28***k* (see FIG. **13**), so that this interstage coupling electrode **28***f* does not contact with other conductors. In the same manner, an input/output coupling electrode **28***g* is provided within the region of the cutout **28***k*, so that this input/output coupling electrode **28***g* does not contact with other conductors.

The arrangement of the interstage coupling electrode **28***f* and the input/output coupling electrode **28***g* is different from that of the first embodiment. Namely, the interstage coupling electrode and the input/output coupling electrode are separately provided on different side surfaces of the dielectric resonator in the first embodiment. On the contrary, the second embodiment provides the cutout **28***k* on only one outer side surface **28***h* and disposes the electrodes **28***f* and **28***g* within the region of this cutout **28***k*.

The other dielectric resonator **29** comprises: a dielectric base body **29***a*, a through hole **29***b*, an outer conductor **29***c*, an inner conductor **29***d*, a connecting conductor **29***e*, an interstage coupling electrode **29***f*, an input/output coupling electrode **29***g*, an outer side surface **29***h*, an open end **29***j*, and a cutout **29***k* (see FIG. **13**). The like parts between the dielectric resonators **28** and **29** are denoted by the same reference alphabet throughout views. (For example, the dielectric base body **28***a* is substantially identical with the dielectric base body **29***a*) However, as apparent from FIG. **13**, the relationship between the dielectric resonator **28** and the dielectric resonator **29** are mirror symmetry. Therefore, in production of each dielectric resonator, it is necessary to pay attention to the positional relationship between the electrodes **28***f*, **28***g* and **29***f*, **29***g*.

More specifically, the dielectric resonator **28** and the dielectric resonator **29** are connected by means of, for example, cream solder in such a manner that the outer side surfaces **28***h* and **29***h* do not confront with each other and are placed on the same plane. Furthermore, there is provided a terminal **30** electrically connecting both the electrodes **28***f* and **29***f*. This terminal **30** is made of conductive material, such as silver, copper, and aluminum. Conductive bonding material, such as solder, is used to connect the terminal **30** with the electrodes **28***f*, **29***f*. Furthermore, the electrode **28***g* is connected with a terminal **31** and the electrode **29***g* is connected with a terminal **32** by means of conductive bonding material, such as solder. The terminals **31** and **32** are made of conductive material, such as copper and aluminum.

Furthermore, the outer conductors **28***c*, **29***c*, inner conductors **28***d*, **29***d*, connecting conductors **28***e*, **29***e*, electrodes **28***f*, **29***f*, and electrodes **28***g*, **29***g* (hereinafter, these components respectively are referred to as conductor film) are basically thin film made of conductive material such as copper and silver. The thickness of the film is approximately 5 μm. Although the conductor film is a single layer in this embodiment, it is needless to say that two or more layer structure can be allowed. Regarding the film thickness of approximately 5 μm, this value should be adequately changed depending on the condition of the dielectric filter in service.

Although the electrodes **28***g*, **29***g* and **28***f*, **29***f* are rectangular in this second embodiment, the configuration of these electrodes **28***g*, **29***g* and **28***f*, **29***f* can be any other shape, such as circle, ellipse, and polygon.

As apparent from the foregoing description, the dielectric filter of this embodiment is very simplified and compact in structure. In particular, the present embodiment no longer requires the central conductor and the dielectric substrate of the conventional dielectric filter. This results in 50% reduction of overall size.

FIG. **14** is a perspective view showing the dielectric filter mounted on a substrate in accordance with the second embodiment of the present invention. In FIG. **14**, a reference numeral **33** represents a printed circuit board constituted by insulating material, such as glass . epoxy resin. Reference numerals **34** and **35** represent input/output pathways formed on the printed circuit board **33**. Similarly, a reference numeral **36** represents a grounded pathway formed on the printed circuit board **33**. The terminal **31** of the dielectric resonator **28** is connected onto the input/output pathway **34** by conductive bonding material, such as solder, and the terminal **32** of the dielectric resonator **29** is connected onto the input/output pathway **35** by conductive bonding material, such as solder. Furthermore, the outer conductors **28***c* and **29***c* of the dielectric resonators **28** and **29** are respectively connected onto the grounded pathway **36** by conductive bonding material, such as solder. The input/output pathways **34**, **35** and the grounded pathway **36** are formed by coating conductive paste, such as Ag paste, on the printed circuit board **33** in a predetermined pattern and then fixing it by printing. Although this embodiment uses the terminal **30** to connect the electrodes **28***f* and **29***f* and uses the terminals **31** and **32** to connect the input/output pathways and the dielectric filter, it is also possible to provide a connecting electrode on the printed circuit board **33** instead of the terminal **30** to connect the electrodes **28***f* and **29***f* (see FIGS. **12**, **13**). The terminals **31** and **32** are also omitted in this case.

More specifically, there is provided a connecting electrode (not shown) between the input/output pathways **34**, **35** made of conductive material. The dielectric resonators **28** and **29** (being not equipped with the terminals **30**, **31** and **32**) are placed on the connecting electrode so that both the electrodes **28***f*, **29***f* (see FIGS. **12**, **13**) contact with the connecting electrode, the input/output terminals **28***g*, **29***g* contact with the input/output pathways **34**, **35**, and the outer conductors **28***c*, **29***c* contact with the grounded conductor **36**. Thereafter, the dielectric resonators **28** and **29** are tightly fixed on the printed circuit board by means of conductive bonding material, such as cream solder. In other words, if the terminal **30** is omitted, no gap is generated between the electrodes **28***g*, **29***g* (see FIGS. **12**, **13**) and the printed circuit board **33**. Therefore, the terminals **31** and **32** are no longer necessary.

The prospective manufacturing methods of the above-described dielectric filter are substantially the same as those of the previously described first embodiment and, therefore, will be no more explained.

Next, a modified embodiment of the second embodiment will be explained.

FIG. **15** is a perspective view showing the modified dielectric filter of the second embodiment of the present invention, and FIG. **16** is an exploded perspective view showing the modified dielectric filter of the second embodiment of the present invention.

The modified embodiment of FIGS. **15** and **16** is different from the dielectric filter of FIGS. **12** and **13** in the configuration of a through hole. The dielectric filter of FIGS. **12**, **13** has the through hole of constant diameter extending from the open end to the opposite end. On the other hand, this modified dielectric filter is different from the embodiment of FIGS. **12**, **13** and characterized in that the through hole has a stepped portion. That is, the dielectric filter **28** has a dielectric base body **28***a* formed with a centrally axially extending through hole. The through hole consists of a large hole **28***m* and a small hole **28***n* (see FIG. **15**) extending centrally and axially and communicated with each other. The large hole **28***m* is positioned near the open end and has a square cross section, while the small hole **28***n* has a circular cross section. An inner conductor **28***q* is provided on the inside surface of this through hole. Likewise, the other dielectric filter **29** has a dielectric base body **29***a* and a centrally axially extending through hole consisting of a large hole **29***m* and a small hole **29***n* (see FIG. **15**) extending centrally and axially and communicated with each other. The large hole **29***m* is positioned near the open end and has a square cross section, while the small hole **29***n* has a circular cross section. An inner conductor **29***q* is provided on the inside surface of this through hole. Providing the stepped portion in the through hole and forming the square holes **28***m*, **29***m* near the open end so as to have a larger cross section than the corresponding holes **29***n*, **29***m* is advantageous in increasing not only the input/output coupling capacitance between the electrode **28***g* and the inner conductor **28***q* and between the electrode **29***g* and the inner conductor **29***q* but also the interstage coupling capacitance between the electrode **28***f* (see FIG. **16**) and the inner conductor **28***q* and between the electrode **29***f* (see FIG. **16**) and the inner conductor **29***q*. Thus, it becomes possible to manufacture a wide-band dielectric filter. The remainder of the construction is substantially the same as that of FIGS. **12** and **13**.

Third Embodiment

FIGS. **17** and **18** are perspective and exploded views showing a dielectric filter of the third embodiment of the present invention. In FIGS. **17** and **18**, reference numerals **37** and **38** represent dielectric resonators. Hereinafter, taking the dielectric resonator **37** of these two dielectric resonators, a construction of the dielectric resonator will be explained. A dielectric base body **37***a* made of dielectric material, such as $BaO—TiO_2—Nd_2O_3$, $BaO—TiO_2$, $ZrO_2—SnO_2—TiO_2$, $BaO—Sm_2O_3—TiO_2$, is formed with a centrally axially extending through hole **37***b*.

The dielectric base body **37***a* has an outer configuration of rectangular parallelepiped having a square cross section, while the through hole **37***b* has a circular cross section. An outer conductors **37***c* is provided on the outer side surface of the dielectric base body **37***a* so as to surround it. An inner conductor **37***d* is provided along the inner side surface of the through hole **37***b*. The outer conductor **37***c* and the inner conductor **37***d* are connected with each other via a connecting conductor **37***e*. This connecting conductor **37***e* is provided on a closed end surface, i.e. a base of the rectangular parallelopiped, of the dielectric base body **37***a* as explained in the first embodiment with reference to FIGS. **35** and **36**. Of four outer side surfaces of the dielectric base body **37***a*, two side surfaces **37***i* and **37***h* are partly cut off so that the dielectric base body **37***a* is bared near the open end **37***j*. Namely, cutouts **37***p* (see FIG. **18**) and **37***k* of the outer conductor **37***c* are formed on the two side surfaces **37***i* and **37***h*, respectively, near the open end **37***j* of the dielectric base body **37***a*.

Furthermore, an interstage coupling electrode **37***f* is provided within the region of the cutout **37***k* on the outer side surface **37***h*, so that this interstage coupling electrode **37***f* does not contact with other conductors. In the same manner, an input/output coupling electrode **37***g* (not shown) is provided within the region of the cutout **37***p* on the outer side surface **37***i*, so that this input/output coupling electrode does not contact with other conductors. The cutout **37***p* extends beyond the corner and along an adjacent outer side surface—a surface to be confronted with the printed circuit board. It will be preferable to connect an L-shaped terminal **39** (see FIG. **17**) with the input/output coupling electrode. Namely, depending on the condition of the printed circuit board on which the dielectric filter is mounted, the terminal **39** and others are connected with the input/output coupling electrode. Then, the terminal **39** is firmly connected with a conductive film (e.g. input/output pathway) on the printed circuit board by means of solder or the like. Instead of providing the terminal **39**, it will be also possible to directly connect the input/output coupling electrode with the conductive film on the printed circuit board by means of solder or the like. For the latter case, the cutout **37***p* extending within the region of the surface to be confronted with the printed circuit board serves to prevent the solder electrically connecting the conductive film and the input/output coupling electrode from contacting with the outer conductor **37***c*.

Likewise, the other dielectric resonator **38** comprises: a dielectric base body **38***a*, a through hole **38***b*, an outer conductor **38***c*, an inner conductor **38***d*, a connecting conductor **38***e*, an interstage coupling electrode **38***f*, an input/

output coupling electrode **38***g* (which is similar to the input/output coupling electrode **37***g* of the dielectric resonator **37**), outer side surfaces **38***h* and **38***i*, an open end **38***j*, and cutouts **38***k*, **38***p*. The like parts between the dielectric resonators **37** and **38** are denoted by the same reference alphabet throughout views. (For example, the dielectric base body **37***a* is substantially identical with the dielectric base body **38***a*)

However, as apparent from FIG. **18**, the relationship between the dielectric resonator **37** and the dielectric resonator **38** are mirror symmetry. Therefore, in production of each dielectric resonator, it is necessary to pay attention to the positional relationship between the electrodes **37***f*, **37***g* and **38***f*, **38***g*.

Furthermore, the electrode **38***g* may be connected with a terminal **39** (see FIG. **17**) depending on the condition of the printed circuit board on which the dielectric resonator **38** is mounted, in the same manner as the dielectric resonator **37**.

More specifically, the dielectric resonator **37** and the dielectric resonator **38** are connected by means of, for example, cream solder in such a manner that the electrodes **37***f* and **38***f* confront and contact with each other and the electrodes **37***g* and **38***g* are placed in parallel and remotely opposed relationship so as to face both sides of the resonators. This is because these dielectric resonators are disposed in mirror symmetry relationship as described before.

Furthermore, the outer conductors **37***c*, **38***c*, inner conductors **37***d*, **38***d*, connecting conductors **37***e*, **38***e*, electrodes **37***f*, **38***f*, and electrodes **37***g*, **38***g* (hereinafter, these components respectively are referred to as conductor film) are basically thin film made of conductive material such as copper and silver. The thickness of the film is approximately 5 μm. Although the conductor film is a single layer in this embodiment, it is needless to say that two or more layer structure can be allowed. Regarding the film thickness of approximately 5 μm, this value should be adequately changed depending on the condition of the dielectric filter in service.

Although the electrodes **37***g*, **38***g* and **37***f*, **38***f* are rectangular in this third embodiment, the configuration of these electrodes **37***g*, **38***g* and **37***f*, **38***f* can be any other shape, such as circle, ellipse, and polygon.

As apparent from the foregoing description, the dielectric filter of this embodiment is very simplified and compact in structure. In particular, the present embodiment no longer requires the central conductor and the dielectric substrate of the conventional dielectric filter. This results in 50% reduction of overall size.

FIGS. **19** and **20** are perspective views showing the dielectric filter mounted on a substrate in accordance with the third embodiment of the present invention. In FIG. **19**, a reference numeral **40** represents a printed circuit board constituted by insulating material, such as glass . epoxy resin. Reference numerals **41** and **42** represent input/output pathways formed on the printed circuit board **40**. Similarly, reference numerals **43**, **44** represent grounded pathways formed on the printed circuit board **40** so as to sandwich the input/output pathways **41**, **42**, respectively. The terminal **39**, connected to the input/output coupling electrode **37***g* (not shown) of the dielectric resonator **37**, is connected onto the input/output pathway **41** by conductive bonding material, such as solder. And the terminal **39**, connected to the electrode **38***g* of the dielectric resonator **38** is connected onto the input/output pathway **42** by conductive bonding material, such as solder. Furthermore, the outer conductors **37***c* and **38***c* of the dielectric resonators **37** and **38** are

connected onto the grounded pathways **43**, **44**, respectively, by conductive bonding material, such as solder. The input/output pathways **41**, **42** and the grounded pathways **43**, **44** are formed by coating conductive paste, such as Ag paste, on the printed circuit board **40** in a predetermined pattern and then fixing it by printing.

Furthermore, as shown in FIG. **20**, the terminal **39** can be omitted. Namely, in mounting the dielectric filter onto the printed circuit board **40**, the input/output coupling electrode **37***g* of the dielectric resonator **37** and the electrode **38***g* of the dielectric resonator **38** can be directly connected with the input/output pathways **41** and **42** by means of a conductive bonding material **45**, such as solder. In this case, the conductive bonding material **45** should be spaced from the outer conductor **38***g* (as the outer conductor **37***g* of the dielectric resonator **37** is spaced from the conductive material).

The prospective manufacturing methods of the above-described dielectric filter are substantially the same as those of the previously described first embodiment and, therefore, will be no more explained.

FIG. **21** shows a graph showing the comparison of damping characteristics outside the band with respect to frequencies between the first and third embodiments. In FIG. **21**, a curve A represents the damping characteristics of the third embodiment and a curve B represents the damping characteristics of the first embodiment. As understood from FIG. **21**, the third embodiment can improve the damping amount outside the band.

In the same manner as the first and second embodiments, the third embodiment can form the through holes provided in the dielectric base bodies **37***a*, **38***a* to have a stepped portion as shown in FIG. **15**. With this arrangement, the input/output coupling capacitance can be increased and also the interstage coupling capacitance can be enlarged. Thus, it becomes possible to obtain a wide-band dielectric filter.

The remainder of the construction is substantially the same as that of FIGS. **17** and **18**.

Fourth Embodiment

FIGS. **22** and **23** are perspective and exploded views showing a dielectric filter of the fourth embodiment of the present invention. In FIGS. **22** and **23**, reference numerals **46** and **47** represent dielectric resonators. Hereinafter, taking the dielectric resonator **46** of these two dielectric resonators, a construction of the dielectric resonator will be explained. A dielectric base body **46***a* made of dielectric material, such as BaO—TiO_2—Nd_2O_3, BaO—TiO_2, ZrO_2—SnO_2—TiO_2, BaO—Sm_2O_3—TiO_2, is formed with a centrally axially extending through hole **46***b*. The dielectric base body **46***a* has an outer configuration of rectangular parallelepiped having a square cross section, while the through hole **46***b* has a circular cross section. An outer conductors **46***c* is provided on the outer side surface of the dielectric base body **46***a* so as to surround it. An inner conductor **46***d* is provided along the inner side surface of the through hole **46***b*. The outer conductor **46***c* and the inner conductor **46***d* are connected with each other via a connecting conductor **46***e*. This connecting conductor **46***e* is provided on a closed end surface, i.e. a base of the rectangular parallelepiped, of the dielectric base body **46***a* as explained in the first embodiment with reference to FIGS. **35** and **36**. Of four outer side surfaces of the dielectric base body **46***a*, two side surfaces **46***i* and **46***h* (see FIG. **22**) are partly cut off so that the dielectric base body **46***a* is exposed near the open end **46***j*. Namely, cutouts **46***p* and **46***k* (see FIG. **23**) of the outer conductor **46***c* are formed on the two side surfaces **46***i* and

46*h*, respectively, near the open end **46***j* (see FIG. **23**) of the dielectric base body **46***a*.

Furthermore, an interstage coupling electrode **46***f* is provided within the region of the cutout **46***k* on the outer side surface **46***h*, so that this interstage coupling electrode **46***f* does not contact with other conductors as depicted in FIG. **23**. In the same manner, an input/output coupling electrode (not shown) is provided within the region of the cutout **46***p* on the outer side surface **46***i*, so that this input/output coupling electrode does not contact with other conductors. The cutout **46***p* extends beyond the corner and along an adjacent outer side surface—a surface to be confronted with the printed circuit board. It will be preferable to connect an L-shaped terminal (not shown) with the input/output coupling electrode. Namely, depending on the condition of the printed circuit board on which the dielectric filter is mounted, the terminal and others are connected with the input/output coupling electrode. Then, the terminal is firmly connected with a conductive film (e.g. input/output pathway) on the printed circuit board by means of solder or the like. Instead of providing the terminal, it will be also possible to directly connect the input/output coupling electrode with the conductive film on the printed circuit board by means of solder or the like. For the latter case, the cutout **46***p* extending within the region of the surface to be confronted with the printed circuit board serves to prevent the solder electrically connecting the conductive film and the input/output coupling electrode from contacting with the outer conductor **46***c*.

Likewise, the other dielectric resonator **47** comprises: a dielectric base body **47***a*, a through hole **47***b*, an outer conductor **47***c*, an inner conductor **47***d*, a connecting conductor **47***e*, an interstage coupling electrode **47***f* (which is similar to the interstage coupling electrode **46***f* of the dielectric resonator **46**), an input/output coupling electrode **47***g* (which is similar to the input/output coupling electrode **47***f* of the dielectric resonator **46** as depicted in FIG. **23**), outer side surfaces **47***h* and **47***i*, an open end **47***j*, and cutouts **47***k* (not shown in FIGS. **22** and **23**), **47***p*. The like parts between the dielectric resonators **46** and **47** are denoted by the same reference alphabet throughout views. (For example, the dielectric base body **46***a* is substantially identical with the dielectric base body **47***a*) Furthermore, the electrode **47***g* may be connected with a terminal depending on the condition of the printed circuit board on which the dielectric resonator **47** is mounted, in the same manner as the dielectric resonator **46**.

More specifically, the dielectric resonator **46** and the dielectric resonator **47** are connected by means of, for example, cream solder in such a manner that the electrodes **46***f* and **47***f* confront and contact with each other and the input/output coupling electrodes **47***g* are placed in parallel and remotely opposed relationship so as to face both sides of the resonators. Furthermore, the dielectric resonators **46** and **47** are placed in opposed relationship so that respective open ends thereof face opposite directions.

Furthermore, the outer conductors **46***c*, **47***c*, inner conductors **46***d*, **47***d*, connecting conductors **46***e*, **47***e*, electrode **46***f* as well as the interstage coupling electrode of the dielectric resonator **47**, and electrode **47***g* as well as the input/output coupling electrode of the dielectric resonator **46** (hereinafter, these components are referred to as conductor film) are basically thin film made of conductive material such as copper and silver. The thickness of the film is approximately 5 μm. Although the conductor film is a single layer in this embodiment, it is needless to say that two or more layer structure can be allowed. Regarding the film thickness of approximately 5 μm, this value should be adequately changed depending on the condition of the dielectric filter in service.

Although the electrode **47***g* (as well as the input/output coupling electrode of the dielectric resonator **46**) and the electrode **46***f* (as well as the interstage coupling electrode of the dielectric resonator **47**) are rectangular in this embodiment, the configuration of these electrodes can be any other shape, such as circle, ellipse, and polygon.

As apparent from the foregoing description, the dielectric filter of this embodiment is very simplified and compact in structure. In particular, the present embodiment no longer requires the central conductor and the dielectric substrate of the conventional dielectric filter. This results in 50% reduction of overall size.

In the same manner as the first and second embodiments, this embodiment can form the through hole to have a stepped portion as shown in FIG. **15**. With this arrangement, the input/output coupling capacitance can be increased and also the interstage coupling capacitance can be enlarged. Thus, it becomes possible to obtain a wide-band dielectric filter.

The remainder of the construction is substantially the same as that of FIGS. **17** and **18**.

Variations of First to Fourth Embodiments

Although the above first to fourth embodiments are explained based on a dielectric filter consisting of two dielectric resonators, the same effect will be obtained even if more than two dielectric resonators are assembled as shown in FIGS. **24**, **25** and **26**.

FIG. **24** is a perspective view showing a modified dielectric filter of the first embodiment, wherein three dielectric resonators are assembled. In FIG. **24**, reference numerals **11** and **12** represent dielectric resonators having the same construction as the above-described first embodiment. A reference numeral **48** represents a dielectric resonator interposed between the dielectric resonators **11** and **12**. The dielectric resonator **48** has interstage coupling electrodes **48***a*, **48***b* on the opposite outer side surfaces and has no input/output coupling electrode. The electrode **48***a* is connected with the interstage coupling electrode **11***f* of the dielectric resonator **11**, and the electrode **48***b* is connected with the interstage coupling electrode **12***f* of the dielectric resonator **12**. In this manner, when the dielectric filter includes not less than three resonators, the dielectric resonators equipped with both interstage and input/output coupling electrodes (hereinafter referred to as end resonators) are placed at both ends. Then, one or more dielectric resonators equipped with only interstage coupling electrodes (hereinafter referred to as interstage resonators) are interposed in series between the two end resonators, so that mutually confronting interstage coupling electrodes are connected one another. With this arrangement, the dielectric filter of the first embodiment can include not less than three dielectric resonators.

FIG. **25** is a perspective view showing a modified dielectric filter of the second embodiment, wherein three dielectric resonators are assembled. In FIG. **25**, reference numerals **28** and **29** represent dielectric resonators having the same construction as the above-described second embodiment. A reference numeral **49** represents a dielectric resonator interposed between the dielectric resonators **28** and **29**. The dielectric resonator **49** has interstage coupling electrodes **49***a*, **49***b* on the same outer side surface and has no input/output coupling electrode. The electrode **49***a* is connected with the interstage coupling electrode **28***f* of the dielectric resonator **28** through a terminal **50**, and the electrode **49***b* is connected with the interstage coupling electrode **29***f* of the dielectric resonator **29** through another terminal **50**. In this manner, when the dielectric filter includes not less than three resonators, the dielectric resonators equipped with both interstage and input/output coupling electrodes (hereinafter referred to as end resonators) are placed at both ends. Then, one or more dielectric resonators equipped with only interstage coupling electrodes (hereinafter referred to as interstage resonators) are interposed in series between the two end resonators, so that mutually confronting interstage coupling electrodes are connected one another. With this arrangement, the dielectric filter of the second embodiment can include not less than three dielectric resonators.

FIG. **26** is a perspective view showing a modified dielectric filter of the third embodiment, wherein three dielectric resonators are assembled. In FIG. **26**, reference numerals **37** and **38** represent dielectric resonators having the same construction as the above-described third embodiment. A reference numeral **51** represents a dielectric resonator interposed between the dielectric resonators **37** and **38**. The dielectric resonator **51** has interstage coupling electrodes **51***a*, **51***b* on the opposite outer side surfaces and has no input/output coupling electrode. The electrode **51***a* is connected with the interstage coupling electrode **37***f* of the dielectric resonator **37**, and the electrode **51***b* is connected with the interstage coupling electrode **38***f* of the dielectric resonator **38**. In this manner, when the dielectric filter includes not less than three resonators, the dielectric resonators equipped with both interstage and input/output coupling electrodes (hereinafter referred to as end resonators) are placed at both ends. Then, one or more dielectric resonators equipped with only interstage coupling electrodes (hereinafter referred to as interstage resonators) are interposed in series between the two end resonators, so that mutually confronting interstage coupling electrodes are connected one another. With this arrangement, the dielectric filter of the third embodiment can include not less than three dielectric resonators.

In the same manner, the dielectric filter of the fourth embodiment can include not less than four resonators by interposing one or more interstage resonators between two end resonators.

Fifth Embodiment

FIGS. **29** and **30** are perspective and exploded views showing a dielectric filter of the fifth embodiment of the present invention. In FIGS. **29** and **30**, reference numerals **111** and **112** represent dielectric resonators. Hereinafter, taking the dielectric resonator **111** of these two dielectric resonators, a construction of the dielectric resonator will be explained. A dielectric base body **111***a* made of dielectric material, such as BaO—TiO_2—Nd_2O_3, BaO—TiO_2, ZrO_2—SnO_2—TiO_2, BaO—Sm_2O_3—TiO_2, Ln_2O_3—BaO—TiO_2 series, is formed with a centrally axially extending through hole **111***b*.

The dielectric base body **111***a* has an outer configuration of rectangular parallelepiped having a square cross section, while the through hole **111***b* has a circular cross section. An outer conductors **111***c* is provided on the outer side surface of the dielectric base body **111***a* so as to surround it. An inner conductor **111***d* is provided along the inner side surface of the through hole **111***b*. The outer conductor **111***c* and the inner conductor **111***d* are connected with each other via a connecting conductor **111***e*. This connecting conductor **111***e* is provided on a closed end surface, i.e. a base of the rectangular parallelepiped, of the dielectric base body **111***a* as explained in the first embodiment with reference to FIGS. **35** and **36**. Of four outer side surfaces of the dielectric base body **111***a*, one side surface **111***i* (see FIG. **29**) is partly cut off so that the dielectric base body **111***a* is bared near the open end **111***j*. Namely, a cutout **111***k* (see FIG. **29**) of the outer conductor **111***c* is formed near the open end of the dielectric base body **111***a*.

Furthermore, an interstage electrode **111***f* is provided on an outer side surface **111***l* (see FIG. **30**), which is adjacent and perpendicular to the outer side surface **111***i*, near the open end **111***j*. The electrode **111***f* is provided within the region of a cutout **111***o* (see FIG. **30**) formed on the outer side surface **111***l* (see FIG. **30**), so that the electrode **111***f* does not contact with the outer conductor **111***c*.

Moreover as depicted in FIG. **30**, there is provided input/output electrodes **111***g* and **111***h* along outer side surfaces **111***m*, **111***n* near the open end **111***j*. These electrodes **111***g* and **111***h* are provided within the region of a cutout **111***p* formed on the outer side surfaces **111***m*, **111***n*.

Likewise, the other dielectric resonator **112** comprises substantially the same components: namely, a dielectric base body **112***a*, a through hole **112***b*, an outer conductor **112***c*, an inner conductor **112***d*, a connecting conductor **112***e*, an interstage coupling electrode **112***f*, input/output coupling electrodes **112***g*, **112***h*, outer side surfaces **112***i* (see FIG. **29**), **112***l*, **112***m* and **112***n* (see FIG. **30**), an open end **112***j*, and cutouts **112***k* (see FIG. **29**), **112***o* and **112***p*. The like parts between the dielectric resonators **111** and **112** are denoted by the same reference alphabet throughout views. (For example, the dielectric base body **111***a* is substantially identical with the dielectric base body **112***a*) However, as apparent from FIG. **30**, the relationship between the dielectric resonator **111** and the dielectric resonator **112** are mirror symmetry. Therefore, in production of each dielectric resonator, it is necessary to pay attention to the positional relationship between the electrodes **111***f*, **111***g*, **111***h* and **112***f*, **112***g*, **112***h*.

More specifically, the dielectric resonator **111** and the dielectric resonator **112** are connected by means of, for example, cream solder in such a manner that the electrodes **111***f* and **112***f* confront and contact with each other and the electrodes **111***g* and **112***g* are placed in opposed and parallel relationship and the electrodes **111***h* and **112***h* are placed on the same plane.

This is because the dielectric resonators **111** and **112** are disposed in mirror symmetry relationship as explained previously.

Furthermore, the outer conductors **111***c*, **112***c*, inner conductors **111***d*, **112***d*, connecting conductors **111***e*, **112***e*, electrodes **111***f*, **112***f*, **111***g*, **112***g*, **111***h*, **112***h* (hereinafter, these components respectively are referred to as conductor film) are basically thin film made of conductive material such as copper and silver. The thickness of the film is approximately 5 μm. Although the conductor film is a single layer in this embodiment, it is needless to say that two or more layer structure can be allowed. Regarding the film thickness of approximately 5 μm, this value should be adequately changed depending on the condition of the dielectric filter in service.

FIG. **31** is a graph showing a relationship between an area S of the cutouts **111***k* and **112***k*—an area defined by Z1×Z2 in FIG. **29**—and an interstage coupling degree K in accordance with the fifth embodiment of the present invention.

As understood from FIG. **31**, the interstage coupling degree K increases with increasing area S of the cutouts **111***k* and **112***k*. Furthermore, the interstage coupling degree K can be enlarged when compared with the conventional one (as illustrated by the "Prior Art" point located between the values two and three on the vertical axis). Thus, it becomes possible to provide a wide-band dielectric filter.

A manufacturing method of the above-described dielectric filter will be explained hereinafter.

First of all, starting materials (for example, BaO, TiO_2, Nd_2O_3 or the like) are blended at a predetermined ratio. Then, the blended material is mixed by using a mill or else. Next, the mixed material is granulated by using a spray dryer or the like, so as to adjust the particle size and add binder. Subsequently, the granulated material is pelletized by a dry press so as to be formed into a predetermined shape. In turn, the pelletized material is sintered in a kiln at the temperature of 1300° C. to 1400° C. Thus, the dielectric base body **111***a* of cylindrical shape is obtained. Then, the conductor film is formed on the dielectric base body **111***a*. There are various method for forming the conductor film, several of which will be explained below.

A first method is applied in a case where copper is used as a material constituting the conductor film. The surface of the dielectric base body **111***a* is roughened by a barrelling machine or a blast device. Thereafter, the dielectric base body **111***a* is processed by etching until the roughness of the surface of the dielectric base body **111***a* becomes 5 μm to 9 μm. Etchant to be used in this etching will be, for example, HF—HNO_2 series. Subsequently, all the surface of the dielectric base body **111***a* is processed by stannous chloride or the like to give sensitivity. Then, palladium qualifying as catalytic metal is attached on all the surface of the dielectric base body **111***a*. And, a resist film is partially formed on the dielectric base body **111***a*.

Namely, this resist film **23** defines a region on which no conductor film of the dielectric base body **111***a* is provided—a region becoming the cutout **111***k*, **111***o* and **111***p*. In the formation of this resist film, resist ink is coated on the dielectric base body **111***a* by the use of printing technology or transfer technology or else and then thus printed resist ink is dried until it hardens. Next, on thus manufactured dielectric base body **111***a*, there is formed a thin, first copper film by the electroless copper plating method. In this case, the first copper film is selectively formed only within a region where the resist film is not provided.

Subsequently, a second copper film is laminated on the first copper film by the electrolytic copper plating to form the conductor film whose thickness is approximately 5 μm. After the resist film is removed by solvent or else, the electrodes are formed. Although the above manufacturing method coats the resist ink on the predetermined portion of the dielectric base body **111***a* using the printing technology and then dries and hardens the resist ink, another manufacturing method will allow the use of a photosensitive resist as a resist. That is, after the catalytic metal, such as palladium, is attached on the dielectric base body **111***a*, photosensitive resist is coated on all the surface of the dielectric base body **111***a*. Then, a predetermined portion of the photosensitive resist is exposed and hardened. Thereafter, the portion not being hardened by exposure is washed away by developing solution. Then, the electrodes will be obtained.

Another manufacturing method will form the conductor film on the dielectric base body **111***a* by coating Ag paste on the entire surface of the dielectric base body **111***a* by printing or the like method, drying this Ag paste, and applying a thermal treatment at the temperature of 800° C. to 900° C.

Thereafter, the unnecessary portion of the conductor film may be removed by using the etching technology, such as chemical etching or dry etching. Thus, the electrodes are provided at the predetermined places.

Still another manufacturing method will form the electrodes, after forming the conductor film on the entire surface of the dielectric base body **111***a*, by cutting or laser machining the surface of the dielectric base body **111***a* to physically remove the predetermined portion of the surface.

The dielectric resonators **111** and **112** thus constructed are disposed in such a manner that the electrodes **111***f* and **112***f* confront with each other. Then, the outer conductors **111***c* and **112***c* are connected by means of cream solder or the like. Similarly, the electrodes **111***f* and **112***f* are connected by means of cream solder or the like.

Although this embodiment is explained based on the cutouts **111***k* and **112***k* shown in FIG. **29**, the cutouts **11***k* and **112***k* can be made variously as long as they reach the open end **29***m*. Furthermore, it will be allowed to provide the cutout on either of these dielectric resonators **111** and **112**.

Sixth Embodiment

FIGS. **32** and **33** are perspective and exploded views showing a dielectric filter of the sixth embodiment of the present invention. In FIGS. **32** and **33**, reference numerals **301** and **302** represent dielectric resonators. Hereinafter, taking the dielectric resonator **301** of these two dielectric resonators, a construction of the dielectric resonator will be explained. A dielectric base body **301***a* made of dielectric material, such as BaO—TiO_2—Nd_2O_3, BaO—TiO_2, ZrO_2—SnO_2—TiO_2, BaO_2—Sm_2O_3—TiO_2, is formed with a centrally axially extending through hole **301***b*. The dielectric base body **301***a* has an outer configuration of rectangular parallelopiped having a square cross section, while the through hole **301***b* has a circular cross section. An outer conductors **301***c* is provided on the outer side surface of the dielectric base body **301***a* so as to surround it. An inner conductor **301***d* is provided along the inner side surface of the through hole **301***b*. The outer conductor **301***c* and the inner conductor **301***d* are connected with each other via a connecting conductor **301***e*. This connecting conductor **301***e* is provided on a closed end surface, i.e. a base of the rectangular parallelepiped, of the dielectric base body **301***a* as explained in the first embodiment with reference to FIGS. **35** and **36**. Of four outer side surfaces of the dielectric base body **301***a*, outer side surfaces **301***i*, **301***h* and **301***l* (see FIG. **33**) are partly cut off so that the dielectric base body **301***a* is exposed near the open end **301***j*. Namely, as depicted in FIG. **33** three cutouts **301***p*, **301***k* and **301***m* of the outer conductor **301***c* are formed near the open end of the dielectric base body **301***a*. Furthermore, an interstage electrode **301***f* is provided within the cutout **301***k* formed on the outer side surface **301***h*, so that the electrode **301***f* does not contact with other conductors. Likewise, input/output coupling electrode **301***g* (not shown), **301***n* are provided within the respective cutouts **301***p*, **301***m* formed on the corresponding outer side surfaces **301***i*, **301***l*, so that the electrodes **301***g*, **301***n* do not contact with other conductors. In mounting the dielectric filter on a printed circuit board, the input/output coupling electrodes **301** and **301***n* are directly connected with the conductive film (e.g. input/output pathways) by means of solder or the like.

The other dielectric resonator **302** (see FIGS. **32**, **33**) comprises substantially the same components: namely, a dielectric base body **302***a*, a through hole **302***b*, an outer conductor **302***c*, an inner conductor **302***d*, a connecting conductor **302***e*, an interstage coupling electrode **302***f*, input/output coupling electrodes **302***g* (which is similar to the input/output coupling electrode of the dielectric resonator **301**), **302***n* (see FIG. **33**), outer side surfaces **302***i*, **302***h* (see FIG. **33**), **302***l*, an open end **302***j*, and cutouts **302***p*, **302***m* (see FIG. **33**) and **302***k*. The like parts between the dielectric resonators **301** and **302** are denoted by the same reference alphabet throughout views. (For example, the dielectric base body **301***a* is substantially identical with the dielectric base body **302***a*) However, as apparent from FIG. **33**, the relationship between the dielectric resonator **301** and the dielectric resonator **302** are mirror symmetry. Therefore, in production of each dielectric resonator, it is necessary to pay attention to the positional relationship between the electrodes **301***f*, **301***g*, **301***n* and **302***f*, **302***g*, **302***n*.

More specifically, the dielectric resonator **301** and the dielectric resonator **302** are connected by means of, for example, cream solder in such a manner that the electrodes **301***f* and **302***f* confront and contact with each other and the electrodes **301***g* and **302***g* are placed in opposed and parallel relationship and the electrodes **301***n* and **302** *n* are placed on the same plane. This is because the dielectric resonators **301** and **302** are disposed in mirror symmetry relationship as explained previously.

Furthermore, the outer conductors **301***c*, **302***c*, inner conductors **301***d*, **302***d*, connecting conductors **301***e*, **302***e*, electrodes **301***f*, **302***f*, **301***g*, **302***g*, **301***n*, **302***n* (hereinafter, these components are referred to as conductor film) are basically thin film made of conductive material such as copper and silver. The thickness of the film is approximately 5 μm. Although the conductor film is a single layer in this embodiment, it is needless to say that two or more layer structure can be allowed. Regarding the film thickness of approximately 5 μm, this value should be adequately changed depending on the condition of the dielectric filter in service.

Moreover, as depicted in FIG. **33** the sixth embodiment allows to vary a cutout width H of the cutouts **301***k*, **302***k*, thereby finely adjusting the interstage coupling degree of the filter. Thus, it becomes possible to set the interstage coupling degree at a desired value.

In the same manner as the first and second embodiments, this embodiment can form the through hole to have a stepped portion as shown in FIG. **15**. With this arrangement, the input/output coupling capacitance can be enlarged; thus it becomes possible to obtain a wide-band dielectric filter.

Furthermore, by increasing the inner diameters of the inner conductors **301***d*, **302***d* of the dielectric resonators **301** and **302**, the input/output coupling capacitance and the interstage coupling capacitance can be enlarged. Thus, it becomes possible to provide a wide-band dielectric filter,

The sixth embodiment can include three dielectric resonators as shown in FIG. **34**. In this case, dielectric resonators **301, 302** placed at both ends (hereinafter, referred to as end resonators) are identical with those shown in FIGS. **32** and **34**. A central dielectric resonator **401** has two interstage coupling electrodes formed at opposite outer side surfaces which are to be connected to the confronting interstage coupling electrodes of the end resonators.

As this invention may be embodied in several forms without departing from the spirit of essential characteristics thereof, the present embodiment is therefore illustrative and not restrictive, since the scope of the invention is defined by the appending claims rather than by the description preceding them, and all changes that fall within meets and bounds of the claims, or equivalence of such meets and bounds are therefore intended to embraced by the claims.

What is claimed is:

1. A dielectric filter comprising:

at least two dielectric resonators each including:

a respective dielectric base body including corresponding first, second, third and fourth side surfaces and first and second end surfaces, wherein a respective through hole is provided from the first end surface to the second end surface along a central axis of the corresponding dielectric base body to define a respective inner surface thereof;

a respective outer conductor located on and partially covering the first, second, third and fourth side surfaces of the corresponding dielectric base body, wherein the outer conductor provides an uncovered portion of the first side surface that extends across a width of the respective first side surface and is adjacent to the corresponding first end surface, uncovered portions of the respective second and third side surfaces that are adjacent to each other and bounded by the corresponding outer conductor in three directions, and uncovered portion of the respective fourth side surface that is adjacent to the uncovered portion of the corresponding first side surface and the corresponding first end surface and is separated from the corresponding third side surface by the respective outer conductor;

a respective inner conductor located on the inner surface of the corresponding dielectric base body;

a respective connection conductor located on the second end surface of the corresponding dielectric base body, wherein the respective connection conductor connects the inner conductor to the outer conductor on the corresponding dielectric base body;

a respective interstage coupling electrode located on the uncovered portion of the corresponding first side surface, wherein a respective area of the uncovered portion of the corresponding first side surface extends in at least three directions from the respective interstage coupling electrode and separates the interstage coupling electrode from the corresponding outer conductor; and

a respective input/output coupling electrode located on the uncovered portion of the second and third side surfaces of the corresponding dielectric base body, wherein respective areas of the uncovered portions of the corresponding second and third side surfaces extend in three directions from the input/output coupling electrode and separate the respective input/output coupling electrode from the corresponding outer conductor;

wherein the respective dielectric resonators are connected with each other in such a manner that the outer conductor of a first one of the dielectric resonators is electrically connected to the outer conductor of a second one of the dielectric resonators.

2. A dielectric filter as claimed in claim **1**, wherein the interstage coupling electrode of the first one of the dielectric resonators is electrically connected to the interstage coupling electrode of the second one of the dielectric resonators.

3. A dielectric filter comprising:

at least two dielectric resonators each including:

a respective dielectric base body including corresponding first, second, third and fourth side surfaces and first and second end surfaces, wherein a respective through hole is provided from the first end surface to the second end surface along a central axis of the corresponding dielectric base body to define a respective inner surface thereof;

a respective outer conductor located on the first, second, third and fourth side surfaces of the corresponding dielectric base body, wherein the respective outer conductor covers the fourth side surface and leaves an uncovered portion of the first side surface that is adjacent to the first end surface and bounded in three directions by the corresponding outer conductor, and uncovered portions of the respective second and third side surfaces that are adjacent to each other and bounded by the corresponding outer conductor in three directions;

a respective inner conductor located on the inner surface of the corresponding dielectric base body;

a respective connection conductor located on the second end surface of the corresponding dielectric base body, wherein the respective connection conductor connects the inner conductor to the outer conductor on the corresponding dielectric base body;

a respective interstage coupling electrode located on the uncovered portion of the corresponding first side surface, wherein a respective area of the uncovered portion of the corresponding first side surface extends in three directions from the respective interstage coupling electrode and separates the respective interstage coupling electrode from the corresponding outer conductor; and

a respective input/output coupling electrode located on the uncovered portion of the second and third side surfaces of the corresponding dielectric body, wherein a respective area of the uncovered portions of the corresponding second and third side surfaces extend in three directions from the respective input/output coupling electrode and separate the respective input/output coupling electrode from the corresponding outer conductor;

wherein the respective dielectric resonators are connected with each other in such a manner that the outer conductor of a first one of the dielectric resonators is electrically connected to the outer conductor of a second one of the dielectric resonators.

4. A dielectric filter as claimed in claim **3**, wherein the interstage coupling electrode of the first one of the dielectric resonators is electrically connected to the interstage coupling electrode of the second one of the dielectric resonators.

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